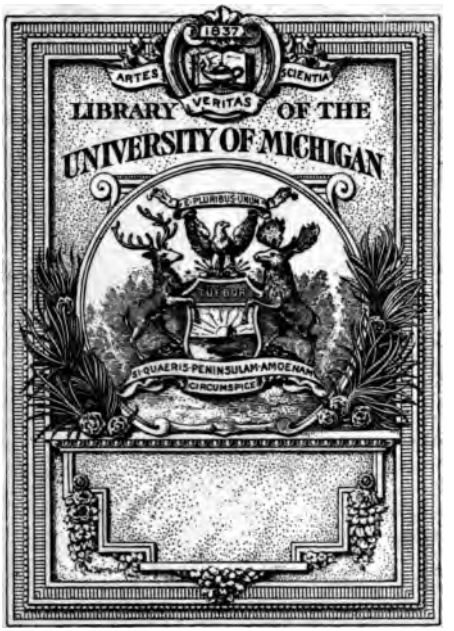
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" Dream ye of peaceful sway?
Dream on who dream it may.
War still is Empire's word,
Peace! by the Victor's sword."

FIRST PRINCIPLES OF PRODUCTION

A STUDY OF THE FIRST PRINCIPLES OF PRODUCTION AND THE RELATION OF SCIENCE TO INDUSTRY.

BY

J. TAYLOR PEDDIE, F.S.S.

Together with Contributions by S. Roy Illingworth, A.R.C.Sc., A.I.C., B.Sc.(Lond.), Sir Norman Lockyer, K.C.B., LL.D., F.R.S. (with Notes by Prof. R. A. Gregory), William Lorimer, LL.D., and Prof. Percy Frankland, F.R.S.

Longmans, Green and Co.
39, Paternoster Row, London
Fourth Avenue & 30th Street, New York
Bombay, Calcutta, and Madras

1915

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INTRODUCTION.

At the conclusion of the great War now progressing it will be necessary for the leaders of British Industry and Science to take stock of their positions. The positions which existed in their respective spheres of activity prior to the declaration of War will have to undergo considerable modification. It is necessary that this shall be done, for the working conditions which we now find about us have been greatly altered, both to our disadvantage and to our advantage. The adverse circumstances which have been forced upon us are in the destruction of Credit Values and in the colossal non-productive expenditure on War material, &c., which is now taking place; the destruction of Capital Values and the non-productive expenditure referred to will all have to be paid for out of the profits earned by Industry for many years to come; and in order to enable Industry to do this without impairing its Trading capacity, it is essential that the working conditions in which it operates should be improved in efficiency.

It is quite clear that Germany must lose the fight which she has entered upon, and it is also clear that she will have to pay very heavy War Costs and

Indemnities to her opponents; which means that the Standard of Wages and Living prevailing in Germany prior to the declaration of War will have to be reduced to a lower level. This is a serious position for those who are engaged in British Industry, and unfortunately cannot be avoided by any treaty, and, combined with the knowledge that German Industry, as a whole, is better organised and more highly efficient than British Industry for dealing with International Trade, imposes upon us the obligation—it is, in fact, a National duty—of organising our forces to meet the altered situation which will exist at the conclusion of the War.

The reduction of Credit Values and Wages in Germany, which will take place in that country when she begins Industrial operations again, means that her costs of production will be on a much lower level than those which prevailed prior to the declaration of War. Germany and Austria will have to live and pay their debts, and it follows, therefore, that competition for International Trade at the conclusion of the War will be keen and strenuous.

The great advantage we have by way of compensation is the breathing space which is now afforded us of putting our working conditions in order. In this task it is necessary that we should secure the co-operation of our men of Science, who are as capable and as great as the men of Science of other Nations; but unfortunately the leaders of

British Industry have hitherto failed to adequately appreciate the magnificent services which our men of Science have rendered gratuitously to the State in the past, and it is to be hoped, in view of the recognition which such men receive in Germany, that in the future a greater inclination to recognise the value of the services which Science can render will be manifested.

The first thing to be done, however, is to evolve a Scheme of National Economics in which shall be shown the value of the services which Science has rendered and can render to Industry. The writer has had this aspect of the question in view in submitting this book to the British Public for consideration.

The general idea which the articles have in view is to open up a series of opportunities from the workmen at the machine to the student at the University, and to assist in this direction an essay by Mr. S. Roy Illingworth on the ' Co-operation of Science and Industry ' is included; also abridgements from the address given by Sir Norman Lockyer, K.C.B., F.R.S., &c., to the British Association at Stockport in 1903 on the ' Influence of Brain Power on History and Industry,' with notes by Professor R. A. Gregory. Sir Norman Lockyer's address, looked at retrospectively, showed a keen penetration, and was, in fact, prophetic. This address is included in his book on ' Education and

National Progress,' which book should be read by all who are interested in the subject. The general Scheme of National Economics outlined in this book will be developed by the Institute of Industry and Science which has been founded for the purpose.

In order, however, to remove any misapprehension which may exist with regard to the question of politics, the writer may say at once that the objects of the Institute are entirely non-political, and is of the opinion that the principles of Free Trade and of Tariffs, if looked at from the standpoint of business and Industry, are not divisible questions, but come under one general survey.

Questions which may arise in these categories should be considered purely on their merit as business propositions, and it is the only consideration which ought to prevail; politics should be entirely eliminated from the consideration of Industrial questions, and it is gratifying to learn that leading Liberal and Unionist manufacturers are agreed upon this point.

In stating these views the writer does not, however, wish to be misunderstood. Politics and Diplomacy, in the spirit in which all British subjects have learned to appreciate them in their own State, must always occupy the foremost position in the life of the Nation. But the forces of Industry, as distinct from Commerce, must surely be mobilised just as much as the Army or the Navy. In the life of the

Nation each have their own particular function to perform. It is upon Industry, however, that the cost of maintaining the Army and Navy eventually falls, and in a crisis like the present it is essential that the forces of Industry are mobilised upon an efficient footing, more especially when it is borne in mind that the enormous expenditure now taking place upon the Army and Navy will have to be liquidated. If the forces of Industry, therefore, are now mobilised and efficiently organised in co-operation with the Dominions, Colonies, and Dependencies, not only shall it be able to defeat the German objective, but at the conclusion of the War it will be able to assist the State to liquidate the War costs more expeditiously.

It is in Industry that the greatest wealth is produced, and the more efficient it becomes, the more will it be able to meet the obligations now thrust upon it. The welfare of all the individuals in the State are concerned in this matter, for the reason that the degree of activity in art, finance, commerce, and credit values is merely a reflex of the degree of activity and efficiency which may be prevalent in Industry.

F. von Bernhardi, in his book on ' Germany and the War,' grasps the principle here involved; he writes as follows (p. 128) :—

' In a great civilised State it is the duties which must be fulfilled—as Treitschke, our great historian

and national politician, tells us—that determine the expenditure, and the great Finance Minister is not the man who balances the national accounts by sparing the national forces, while renouncing the politically indispensable outlay, but he who stimulates all the live forces of the nation to cheerful activity, and so employs them for national ends that the State revenue suffices to meet the admitted political demands. He can only attain this purpose if he works in harmony with the Ministers for Commerce, Agriculture, Industries, and Colonies, in order to break down the restrictions which cramp the enterprise and energy of the individual, to make all dead values remunerative, and to create favourable conditions for profitable business. A great impulse must thrill the whole productive and financial circles of the State, if the duties of the present and the future are to be fulfilled.'

It is a great pity that Von Bernhardi did not devote the same forceful energy to advance the cause of German Kultur through Industry instead of through Militarism. If Germany had followed this course she would have in time become the wealthiest nation; she should have encouraged her surplus population to emigrate to other countries with her principles, and ignored the fact that she lost them as citizens; for the reason that Commerce is international, and that credit values, wealth, and welfare are dependent upon it for sustenance.

The management of the Empire's trade is a business proposition, and it should therefore be considered as such. Mr. Joseph Chamberlain had the keen acumen to observe that something more than mere sentiment was essential if the development of the welfare of the citizens of the British Empire towards a higher standard was to be accomplished. Unfortunately, the only weapon that lay open to him by which he might achieve that purpose was through the medium of tariffs. The Institute of Industry and Science was not then possible.

One of the points the following articles are intended to emphasise is this, that for as long as the industry of the Empire is allowed to remain in the cockpit of party politics, so long will it be impossible to consolidate it into a smooth-running machine. And for the reason that the principles of Free Trade and Tariffs are not divisible questions. The consolidation of the Empire's trade can be accomplished through the science of modern Political Economy—in other words, through the medium of organised industry. The artificial use of a General Tariff is not necessary to accomplish that purpose, but, should it be necessary in very special cases, who are better able to judge than the specialists—*i.e.*, those directly concerned?

If industry is thoroughly organised it will not be necessary to place a Tax on Food Imports to stimulate inter-Imperial trade. The importation of Food

Imports from our Dominions and Colonies in sufficient quantities would need no artificial stimulant. For the reason that if a General Tariff Bill was introduced it would prevent the Agents-General of the Dominions and Colonies from closely co-operating with the leaders of British industry, and that point never seems to have been considered. It will therefore be seen that in business there should be no politics.

The formation of the Institute of Industry and Science did not arise as a consequence of the War. For a number of years the writer has made a special study of National Economics, and as long ago as July, 1910, wrote a short article on ' First Principles of Production,' which was published as an Editorial in *Engineering* in its issue of July 8th, 1910. As it is appropriate in the present case, it is published in the book, with slight additions, and it follows this Introduction.

Since commencing this work the writer has had the pleasure of making the acquaintance of Sir Norman Lockyer, K.C.B., F.R.S., who has held similar views to his own for a much longer time, as is evidenced by the article on ' The Influence of Brain Power on History and Industry,' which forms part of this book. Sir Norman Lockyer's views are developed from the scientific side, whereas the writer's have been developed from the industrial side, but the conclusions are the same.

Von Bernhardi, in his book on 'Germany and the War,' establishes the German principle that 'Might is Right.' Our answer to that should be that 'Right is Might,' and to seek in every possible way to strengthen the Institute of Industry and Science. Ambitious Militarism is Might; Industry and Law is Right. This awful War has cleared away many difficulties that were in the way—we have, in fact, to start afresh—and has brought about the feeling that never again shall Germany devastate industrial life. And the following articles indicate the one and only way by which this object can best be accomplished.

To be a complete success, however, it ought to be followed up with a re-organisation of the educational system in force at our Universities, technical colleges, and secondary schools in Great Britain. The great prosperity of German industry during the last twenty years is in a large measure attributable to their wonderful educational system. In addition to the appreciation which German authorities and professors have given to the organisation of industry and its beneficent results, they have made a point of having it treated as a science—and it is a science.

In Germany the organisation of education and of industry comes under the heading of National Economics, and a large proportion of the students at the Universities graduate as B.Sc. in Commerce. The military authorities in Germany have always

given preference to those applications for commissions made by young men who have acquired a degree at the Universities. This is, of course, an added stimulant, and most of the students prefer the commercial degree because of its usefulness after their military service is complete.

The result of this organisation results in German industry being controlled by very able men. This is particularly so in the chemical industry, and for confirmation of this we have only to turn to the Cotton Industry of Lancashire to observe that the German Chemical Industry has captured 90 per cent. of the British Colour Industry, and that Lancashire will not be able to resume the manufacture of coloured goods on an extended scale until long after the present War is finished, or until the industry is again restored in England.

Let us be candid, and recognise that we have a lot to learn as a nation in methods of organisation. Organisation by no means implies the loss of individuality; on the contrary, the greater the individuality displayed by individuals in organisation, the more efficient does organisation become.

One of our objects must be, therefore, to see that a proper commercial and technical educational system is established in the Universities, technical colleges, and secondary schools in Great Britain. We must establish a B.Sc. degree in Industry, and assist in the drafting of the curriculum. Not only

that, but the Institute of Industry and Science must be prepared to list the names of all students who graduate successfully in commercial and technical subjects, and find employment for them in the great industries of the country. The prospect of being appreciated in the services of industry should be as great a stimulus to the students at British Universities, &c., as the prospect of acquiring a commission in the German Army is to the students in the German Universities.

Not only that, but if the procedure here enunciated is followed it will considerably raise the status of industry, if, indeed, that is needed.

'For he who grasps the problem as a whole,
Has calmed the storm that rages in his soul.'

J. T. P.

FIRST PRINCIPLES OF PRODUCTION.

THE longer we live the more do we recognise that the earning of a living is the main object of human activity. Higher culture is a secondary consideration; man is only ready for culture when his primary wants are satisfied. Faith, hope, and charity are foreign to a hungry man—a fact often overlooked by the prosperous. It is this aspect of human nature that affords an opportunity to Socialists, that gives strength to their movement, that enables them to create bitterness between class and class. And who shall blame the hungry man who adopts Socialism as a creed, if he finds that under existing conditions he cannot secure the basis of all human existence—the earning of a living? But it by no means follows that the hungry man is a good judge of what is the best remedy for the ills which he suffers. The State that encourages its citizens to depend upon social legislation for subsistence, instead of upon individual initiative, is embarking upon a policy fatal alike to itself and the individuals for whom such legislation is intended. Social legislation of that kind is not

a force which helps to build up a man's character, nor does it stimulate that independence of thought so essential to progress. The prosperous condition of the State to-day is due entirely to individual initiative. Similarly, the success of a commercial undertaking can invariably be traced to the same source; it may, perhaps, be bound up in an organisation, but the individuality is nevertheless present.

One of the greatest factors in production is individuality, and Nature has provided that certain men shall possess this quality in a greater degree than others. We know that all men are not equal in ability, and cannot be made so, but it is desirable that all men shall have equal opportunities. In the countries in which this principle finds the widest acceptance economic progress is the greatest. The enormous business activity in the United States of America is in a large measure due to this. One of the advantages of the free play of individuality is that by it the creative class of man—the man with ideas—is brought to the front. Men are divided into three classes—viz :—(1) The creative, the men of genius, the originators. (2) Those who manage for the first—the administrators. (3) Those who do the labour appointed by the first and second—the artisans.

It will be obvious, then, that economic conditions should be such as will ensure a free growth of the first class. As a class it is, numerically, very small,

and even under the best conditions will never grow beyond a certain small proportion. One of the conditions essential for its growth is that we shall not judge a man by what his father was, but by what he is himself. If a man has done good to the community, he is entitled to all the rewards the community can give him, both socially and otherwise. If this principle were agreed to, and if the opportunities were provided, it would be an inspiration for all men to do what they could to prove themselves worthy of respect. We should then bring forward the creators, the men on whom the second and third classes are dependent. It is these economic conditions that Democracy should look for; under such a condition she would learn that the class who ruled her (*i.e.*, the creative) were the providers of her daily bread; under such a system she would abandon Socialism, in the sense in which that word is broadly understood. Instead of the State providing for the individual, it would be recognised that it is the duty of the individual to provide for the State, and also that the State should create conditions conducive to that end. Individuals, however, can only provide for the State through industry, and it should be the function of the State to fit individuals to engage successfully in industry. The extent to which a man can enjoy the pleasures of life is largely dependent upon the opportunities he has in industry, upon experience gained therein,

and upon the amount of thought he gives to the daily task. The more thought and effort one man gives over another the more successful will he be, if he can continue to maintain it.

> ' He only gains his freedom and existence
> Who daily conquers them anew.'

There is no finality. Things that are new to-day are old to-morrow.

As already indicated, man's welfare entirely depends upon industry, and especially upon those industries related to the applied arts. It is in these that man employs his hands and exercises his mind, and it is the duty of the State to afford opportunities for all to gain knowledge which may be turned to account in these industries. It is in industry that man now thrives, and the greater the skill with which he can exercise his hands the greater is the value of his services, not only to himself, but to his employer and the State. Personal service is the greatest asset the individual can give, provided, of course, it is efficient, and the degree of comfort derived therefrom depends entirely upon individual capacity and opportunities.

It has been assumed in the past that capital and labour were the prime factors in wealth production. This is a mistaken belief. It may have been true in the early days of manufacture, when labour played a more important part in production than machinery, but such is not the case to-day. The prime factors

in production are enterprise, experience, and knowledge. There is plenty of capital in the City, and plenty of labour walking the streets, yet they do not produce wealth. Enterprise, aided by experience and knowledge in the form of management, is required to utilise these forces—*i.e.*, capital and labour. Labour is the second factor in production, and capital the third factor. It is essential, however, that management and labour should be highly skilled, for otherwise neither can profitably assist capital.

If capital cannot find profitable employment in industry it will, of necessity, drift to other channels where it can. The welfare of the community is largely dependent upon the free circulation of money among individuals, and it is only through industry that we can hope successfully to achieve this result. The circulation of money is greatest when industry is prosperous. Similarly, when industry is prosperous, so are those businesses associated with the satiation of the wants of man, such as grocers, bakers, clothiers, boot factories, and textile factories, &c. This becomes obvious when it is realised that the wants of the individual increase with his ability to pay.

We have indicated that enterprise, experience, and knowledge are the principal factors in wealth production. This applies to the manager in management, and to the workman at his machine. Modern

economics demand this differentiation. Enterprise, knowledge, and concentration are wealth-productive, and especially so if confined within the sphere of activity in which experience has been gained. In other words, specialisation is the key to profitable production. If these forces are to be utilised for the common good, they will require some form of organisation, and a good organisation requires good management. If these forces are not organised and managed, unemployment will be prevalent in labour and in the higher spheres of life. We perforce see that one of the greatest factors in production is management, and as the evolutionary process advances we recognise this more and more.

The greatest and most modern force in wealth production is organisation. But in using this expression it should not be assumed that individuality is lost in organisation; on the contrary, it is a greater factor than ever, and the more that individuality is developed in individuals in an organisation, the stronger does it become. It is, however, essential that the individuals composing an organisation should work cohesively and for one purpose.

An organisation is not successfully created that does not have within it departmental or sectional organisation, and the severest test to which an organisation can be put as to its efficiency is whether it can maintain a continuity of policy and quality.

In creating an organisation the greatest care should be exercised in avoiding over-centralisation: similarly, in preventing too much decentralisation. Organisation should follow what may be termed natural tendencies, *i.e.*, no individual or section should be cramped for elbow room; arms or action should be allowed to swing naturally. The safest course to follow is the one of natural tendency, for it will allow the fullest scope to the free play of individuality and individual initiative.

The large producer has many advantages which the smaller has not; he can afford to instal new machinery built specially for cheapening production as it appears on the market. As already stated, what is new to-day is old to-morrow, and nowhere is this more true than in engineering. Cheap production is a boon to humanity, for it tends to bring luxury within the reach of all; cheap production in one sphere of activity stimulates further production in other spheres of activity, as it makes possible what in other circumstances might be impossible. As an illustration, let us take the case of a sewing-machine. This is a necessity in most homes, more especially in poor ones. If the cost of producing these machines were high, only the better-class families could afford to buy them; but if the cost of production be low, every family may buy them; and so we come to see that one of the essential factors in human welfare is cheap production. It should be

our main object in life, therefore, to bring about a general recognition of this principle; to see that the economic aspect of it is thoroughly understood by the workman himself. But it should be borne in mind that cheap production will not be brought about by cheap labour or by forcing labour to do more than it is physically capable of doing. Labour should have an adequate return for the services which it performs in production, and labour should not expect more. The value of labour is not determined by the weekly wage each workman receives, but by the services each workman renders in return for the wages received. All first-class firms prefer to pay their employees adequate wages, because the payment of such wages ensures efficient service, and in addition conduces to good relations between employer and employee; and the more the principle is recognised in an organisation, the more successful does it become in proportion. The more this proposition is examined the more will the principle be conceded; for, needless to say, if cheap production or efficiency be not ensured, the trading capacity of the firm becomes crippled, and so good wages cannot continue to be paid.

There are four factors in production—(1) Material. (2) Labour. (3) Establishment charges. (4) Profit. The first and second items are more or less constant in production in a good organisation, whether upon a large or small scale,

but the chief concern of the management of a well-organised company is to cover their establishment charges and earn a profit. If production be upon a large scale, this may be more easily accomplished, because the numerous units of goods produced bear each a proportion of the whole of the charges, thereby ensuring minimum cost per unit of goods; but if production be upon a small scale, each unit of goods produced, bearing its proportion of the whole of the charges, is increased in cost.

It is not therefore surprising to find a tendency towards amalgamation or fusion of interests, as there is thereby achieved the fulfilment of the dominant necessities to efficiency in production. There are also greater opportunities of encouraging that origination and resource which are first essentials in production, as the larger output makes it more easy to offer the financial inducement to the well-trained thinker with experience to ensure capable management. There is, too, the greater possibility of a larger surplus of profit to ensure the prosecution of that experimental research without which there can be no certainty of progress in methods of manufacture and in the improvement of products. These should be the first claims provided for out of revenue, if the future prosperity of any establishment, and, indeed, of the nation, be aimed at. We are not here concerned with the question how these are to be met —whether, in the first case, profit-sharing or bonus

be the medium, or, in the second case, a sound policy of depreciation reserve or direct allowance for experiment; but any failure, either through insufficient profit or improvident finance, must bring its regrettable check to advance. The working classes are most dependent on the maintenance of industrial supremacy, and, while the economy of high wages should be recognised, because thereby some measure of efficiency of labour is ensured, those workmen are short-sighted who show any hesitancy to recognise the importance of the creative originator and the capable manager, with all the financial claims of the cost of production which these involve. The balance-sheet of an industrial company should be examined with a full conception of these necessities. A reserve fund, wisely administered to conform to the sound principles of production which we have enunciated, is as important to the humblest of workers as to the richest capitalist.

As we wax hot in faction,
In battle we wax cold;
Wherefore men fight not as they fought
In the brave days of old.
Then none were for a party,
Then all were for the State;
Then the great man loved the poor,
And the poor man loved the great.

Macaulay.

J. T. P.

THE STATE AND OPPORTUNITY IN INDUSTRY.

"Be this considered. Where thou findest a lie that is oppressing thee, extinguish it; lies exist only to be extinguished; they wail and cry earnestly for extinction."

—CARLYLE.

When Carlyle wrote these words he presented us with a real truism : no man, we believe, had a truer conception of all that was material, or realised more the need for destroying institutions or methods that had outlived their day, and reconstructing new ones in the light of experience. The moral is, of course, applicable to present-day economic problems.

If we seek for the solution of any living problem with this aspect of the question ever in our minds, the solution will become the more easily discernible. Negative and positive attitudes cannot be adopted towards living Industrial problems provided such are a consequence of having followed a natural tendency. The danger, therefore, of allowing these questions to become involved in the fortunes of political parties is obvious, especially when it is considered that experience and knowledge are not always the deciding factor in politics. The natural tendency in

politics is for a divergence of opinion—it is the duty of one party to oppose the other, irrespective of the merits of the case under consideration. But Governments should realise that it is in Industry that men must seek their living, and that being the case, they must needs enlarge its sphere of activity without political bias.

There is a saying in very common use that Trade follows the Flag. It is purely supposititious; trade in mechanical utilities is diverted to that country which possesses the latest experience, science, and knowledge in the methods employed in producing them; and to that country for raw materials which possesses them, and can ship them at the lowest possible cost. But experience, science, and knowledge in creative individuals can only be developed where Industry is active. One is a reflex of the other, and time is necessary. Individuals have their opportunity in the production of mechanical utilities upon a large scale; others have it in the production of specialities. But success in either case is dependent upon the working conditions surrounding the forces of Industry, and which are largely the creation of the State.

Production is a science; and it therefore cannot be admitted that the conditions surrounding Industry fifty years ago can hold good to-day, especially when it is known that chemistry and applied science have altered the methods of the earlier period, and when

it is also known that Industry to-day has to provide and maintain a larger proportion of direct taxation than in the earlier period.

Taxes, dividends, and the payment of wages are the life-blood of the State, and can only be sustained by efficiency in Industry. The increasing burdens of the State are met out of the profits of Industry and Commerce, and should be provided without prejudice to invested capital or tending to increase selling prices. Efficiency in production is the only means by which such favourable conditions can be obtained; it should be the aim of management and labour to continuously decrease costs of production, so as to increase the margin of profit between labour plus material and the selling price.

The level of wages paid is determined solely by the degree of efficiency of methods of production prevailing in Industry; similarly, as a corollary of this proposition, the number of opportunities which may be available in Industry is determined in like manner. One is a reflex of the other. As we have already indicated in the previous article, the value of labour is not determined by the wages individuals may receive in Industry, but by the services individuals can render in return for wages received—*i.e.*, they are rated by comparison with those rendered by competitors, upon the extent of the education they have received or acquired, and the experience and knowledge they possess.

In the previous article we have shown the importance of experience, knowledge, and enterprise in production; we endeavoured to explain that management was really constituted of these three forces, and that certain individuals had a capacity for wielding them to more effect than others. It is to be hoped that labour especially will generously recognise this principle; similarly, it is to be hoped that capital will recognise it, irrespective of class, in the interests of production. A generous recognition of the principles on both sides is essential for the welfare of the community, and in those countries in which it shall receive the widest acceptance will economic progress ultimately be found to be greatest.

Without opportunities, of course we cannot demonstrate the principles here involved. There are two kinds of opportunities:—(1) those which are offered to Industry as a whole, and (2) those offered to individuals; the former can be provided only through the working conditions created by the State, and the second follow as a consequence of the first. If the basis of all human existence is the earning of a living, and if the only opportunity man has of doing this is in Industry, it is obvious that it is the duty of the State to properly develop and protect the working conditions surrounding Industry, and wherever possible to equalise any unfair competition which may be found to prevail in any department of it.

The State is at all times the governing factor in production; she can by her acts create and stimulate Industry; similarly she can by her acts cripple Industry, and this is often done by subjecting Industry to unequal competition and by imposing upon it a severe form of direct taxation and legislation.

So long as all industries in all countries are subjected to the same form of taxation and legislation it matters little, but if the industries of one country only are subjected to a severe form in addition to the open competition of the industries of other countries, then the industrial welfare of the country concerned must necessarily suffer. In this event it follows that the sphere of activity in which individuals acquire experience and knowledge becomes limited in scope. Hence individual opportunities become lessened in proportion to the limitation; and so we come to realise that the State only can increase collective and individual opportunities to the extent necessary.

Subject to the State creating the requisite working conditions there are as many opportunities to-day as there were in the olden days. For instance, a man employed on a machine has his opportunity—he can improve the method of production and so reduce the cost of it. We have already said there is no finality, particularly in engineering, and that what is new to-day is old to-morrow. Par-

ticular care should be exercised, however, to ensure that all efforts on the part of the workman towards making improvements should be properly and adequately recognised. The principle is applicable to all vocations in life.

It should be the principal object of labour to maintain and, if possible, increase credit values, and so increase the circulation of money, but the only way in which this can be accomplished is by labour retaining the confidence of management and capital. A want of confidence is detrimental to cheap production, because the presence of this condition brings about a want of sympathy as between management and labour; we will not say capital and labour, for capital has a will of its own, and, being fluid, has a way of finding other sources of investment, where such disturbing conditions do not prevail.

Whilst capital, labour, and management are independent of one another, yet none of them is of any practical value acting alone; of the three, management is the most important, but even management and labour in combination are helpless acting alone without the aid of capital. Capital cannot be attracted to management and labour unless both are, as a combination, in an efficient condition, and further, unless the working conditions in which they operate lend themselves to profitable production.

We now see that management and labour depend

upon the State for their individual and collective opportunities; that they depend upon the working conditions created by the State for the acquisition of experience and knowledge; that the acquisition of capital for business enterprise largely depends upon the condition of the two previous positions; that the services of management and labour, no matter how efficient, are of no value without the co-operation of those who possess capital; that the State is the governing factor in production, as she only can create the requisite working conditions essential for the purposes indicated; that the success of the policy of ' wake up ' depends as much upon the interest manifested by the State in Industry as upon the interest manifested by those responsible for the management of Industry.

TARIFFS, FREE TRADE AND INDUSTRY.

THE problems of Tariffs and Free Trade have always afforded keen subjects for debate in and outside Parliament and amongst individuals. But the one outstanding feature in all the debates and discussions that have taken place is the extraordinary explanations that have been given by the average politicians in favour of their theories. We are reminded of the truism we have read somewhere that "explanations do not survive; it is the things which are explained."

In discussing such highly technical subjects, one would have imagined that the solutions, if such were required, would have been left to the technologist. If we desire to be cured of any physical weakness we go to our family physician; if we require information upon any subject relating to chemistry we go to the chemist; if we require advice on banking we go to the banker; and in engineering we go to the engineer. But on the subject of Tariffs or Free Trade we go to the politician, and believe he possesses the last word in political economy, or, as it is now termed, National Economics. The specialist is not considered or consulted in this sphere of activity.

We are not now offering criticism against the views of either Free Traders or Tariff Reformers, but merely endeavouring to demonstrate that the regulation of the working conditions in which industry operates should be left to the technologist. The

standardisation of these working conditions is much too complex for the ordinary layman to solve or appreciate. It is difficult to understand why such important business questions as these have been left in the cockpit of party politics so long; perhaps it is due to our admittedly weak educational system, but whatever the cause it must be removed. It is quite clear that no definite line can be drawn across the centre of these problems; viewed from the standpoint of business, they are indivisible questions, and any difficulty that may arise thereunder should be considered purely on its merit, upon the employment it will give to labour, and upon the reflex action it may have on the other industries.

We are not inclined to wholly agree with the view of those political economists who state that the history of political economy is of little value, being for the most part a record of absurd and justly exploded opinions. History has a good deal to teach us as to the manner by which we have arrived at our present position. If any fault is to be found on the historical side, it may be found in the fact that the study of the science of political economy has not reverted to the technologist sooner. Our general knowledge of economics has for the most part come to us from authors who have been largely engaged in the development of political constitutions, and this, incidentally, has led to a study of the conditions that were requisite to improve the lot of

the individuals in the State. But we have to be thankful to the political economists for such knowledge as we possess, even although many of their theories have been exploded.

The world's industry has grown up under the guidance of the political economists of the kind described, but with the advance of science and education conditions have necessarily changed. The leading industrialists of to-day, owing to the advance of science and education, now hold superior positions, and are consequently in a position to state precisely what working conditions are essential to procure the maximum production of wealth from industry.

Such criticisms as we have to offer, of course, refer only to the working conditions surrounding our own industries, and not to those surrounding German industry, in which latter country theoretical views have long since been discarded for the technical and practical.

The Germans have been quietly aggressive in this sphere of activity for some considerable time, but they are not to be blamed for that; rather are they to be commended. Had German Industrialists not allowed German Military Society to reign supreme, they would undoubtedly, as a nation, have gained supremacy in production. But tied to the Military School and obsessed with the idea that such attachment would seal the fate of Great Britain and France

and ultimately lead to considerable expansions of their businesses, they have lost their opportunity; and they richly deserve their fate. German Industrialists ought to have realised that the supremacy of Militarism leads to a low estimate of Industry, and those engaged directly, or indirectly, in it. Not only that, but Industry is made to slave for Militarism, when the latter is supreme; it can be seen, therefore, that such a condition of affairs is a relic of Ancient and Mediæval history, and certainly not suitable for this age of enlightenment: but it would not be possible under the Democratic and Monarchical style of Government, such as we have in Great Britain. It is only possible under absolute Monarchism.

In Sir William Ramsay's short thesis on 'German Methods in Commerce,' issued by the Institute of Industry and Science, he states that 'the German Military organisation had its counterpart in their commercial organisation; that there exists an Imperial Council whose proceedings are kept quiet, but which takes into consideration all obtainable statistics, and, as far as possible, legislates or endeavours to legislate, on the basis of these statistics. Where fiscal duties are found to be required, such a council puts them on; where there is an advantage in taking them off, they are removed. Where cheap transit is possible they give it, for the railways are the property of the State.' Sir William

Ramsay further adds :—' Is it to be expected that any country can fight such a combination as that without adopting, at all events, something of their methods, or without studying their methods and without combining together, if not to imitate them, at least to thwart them? '

This knowledge has been known in a limited circle in Britain for some years past, but the voices that issued the warnings were crying in the wilderness of apathy. The average Britisher exhibits a horribly apathetic attitude towards conditions which exist outside of his own business, and it is to be hoped that the Great War will now open up his mind to the fact that national organisation in industry is as essential as the national organisation we now have in our military and naval forces. The formula of organisation within organisation must be studied, and the working conditions which are necessary to make it a success.

A proper study of the science of production, distribution and management, however, cannot be effected without considering the relations of Free Trade and Tariffs thereto; they form part of the whole question. But certain essentials require to be defined in order to clear the ground and open up the field to impartial consideration, and in doing this we fulfil the purpose of this article.

At Free Trade and Tariff Reform meetings, politicians are often asked the question, ' What is raw

material? ' To very many the question is a thorny one, and the explanations often given have seldom been convincing. We trust politicians will take no offence at these remarks; they are put forward as evidence only against the continuance of the present system. There is no such thing as raw material, it is a misnomer; there is such a thing as raw meat or raw fish; in the dictionary the word raw is defined ' as something without a skin, or an open sore.' It will never be satisfactorily explained why such a descriptive term has been given to iron ore, &c., or how it originated. Even men of science and eminent politicians use the expression, and think it is a great joke to ask on occasion, ' What is raw material? ' The proper interpretation of ' What is raw material? ' is as follows :—What is known as raw material is in reality ' natural material,' and is the agent of production, *i.e.*, substance or matter in its lowest form of utility, such as iron ore, cow hides, raw cotton, coal, corn, wheat, barley, tea, coffee-beans, cocoa-beans, oil, &c., &c., and the moment either of these substances is subjected to a development process, which implies the inclusion of labour, it ceases to be raw material and becomes material. The intermediate stages have always been overlooked, and the distinction must be carefully noted. Examples are given as follows :—Iron ore is a raw material, the pig iron produced therefrom is material; the steel produced from the pig iron is still

material, or may be termed advanced material; the machine produced from the steel is not looked upon as material, but as an article of utility. In other words, the more labour that is employed in the converting processes, the more do you get away from the raw material stage. To bring it nearer home, we will take the case of cow hides; these are raw material, but the moment they are converted into leather they become material, and the moment leather is converted into boots, what do you call them? not raw material, material or advanced material, but boots—articles of utility, made to satiate the wants of man.

To make the point a little more clear, the following quotation from the book written by Professor Charles Lee Raper may be helpful, namely, 'the vast quantities of raw material which are supplied by the agriculturist and miner must be transformed into higher form utilities before they can be of the greatest service and pleasure to man. The consumer does not eat wheat in its raw or elementary form. It must be transformed by the miller into flour, and the flour must be converted into bread. Raw cotton fibre cannot satiate man's want for clothing. It must be carded, spun, and woven; it must be made into some form of cloth before man wears it upon his body. From the cotton fields it must go to the gin, where the fibre is straightened. From the carding room it must go to the spinning machine, where this

straightened fibre is stretched and twisted into thread or yarns. From the spinning machine it must go to the loom, where it is woven into cloth. From the weaving room it must go to the bleaching and dyeing rooms, where it receives the desired colours. In all these stages is the manufacturer; in all of these stages is the man who, by means of all of the agents of production, transforms, time and again, the elementary forms of cotton until they become the thousands of varieties of the higher forms of cotton fabric. This life history of the cotton fabric is substantially the life history of every other kind of finished goods. As we have already said, production is a process of creating forms of things—not material things themselves. The agriculturist and miner produce forms of utilities, or wealth, which we call elementary. The manufacturer changes these elementary forms into higher forms; he creates the higher form utilities.'

The importance of this great question to labour and capital, therefore, will, we hope, not be overlooked, for they are the forces directly concerned. The interests of both in questions relating to production, and especially in the acquisition of raw material, are identical. Any question which may prejudicially affect one interest must affect the other interest. So we come to see how essential it is that all the forces employed in industry should be co-operative, and also that the formula of organisa-

tion within organisation on national lines is as beneficial to the one as it is to the other.

Another important question asked by Tariff Reformers and Free Traders is the following: 'Is the burden of a Tariff entirely borne by the consumer or is it entirely borne by the manufacturer responsible for the shipment of the goods?' It may seem paradoxical, but the reply to this question follows the reply given to 'What is raw material?' One is a corollary of the other, and the answer may be given as follows, namely:—If a tax is imposed on what is herein defined as raw material the consumer pays the tax. But a tax imposed on material or other articles of utility is paid by the shipper in the country of origin. The reason why this is so is that labour cannot compete with Nature in the production of minerals or food products; but labour can compete with labour in the development of raw material into higher form utilities. Therefore, it must not be assumed that in the purchase of material or other articles of utility the consumer, by being limited to a given source for the satisfaction of his requirements, must pay more in consequence. To more clearly define the point, it may be stated that a machine tool can be purchased as cheaply in America, notwithstanding the high American duty, as it can be in England, and in some cases cheaper. If a British machine tool manufacturer desires to compete in America, he must pay the cost of the

American duty; the cost of production in America is about equal to that prevailing in England—hence the reason; and it is attributable to the fact that labour competes with labour. The Ford motor car is manufactured and sold more cheaply in America, with a substantial margin of profit, than any car of a similar kind can be manufactured and sold in England—for the same reason.

Notwithstanding the extraordinary taxation of recent years prices of mechanical utilities are lower to-day than they have ever been, and the whole tendency of prices, other than for food and natural materials, even in countries possessing a protective tariff, is downwards instead of upwards.

The increase in cost of food products is continuous, but it is due to the increased purchasing power of the people; the continuous increase in cost, however, should be checked, and it can be considered the most living problem of to-day.

In first principles of production three cardinal facts reveal themselves, namely :—

(1) That prices of mechanical utilities continuously decrease.

(2) That prices of food products continuously increase, and that no practical steps are being taken to check the increase.

(3) That as the costs of production decrease, wages have a tendency to increase, which might not be necessary if a check were placed

on item 2. In this direction science can be of considerable assistance.

Costs of production of articles of utility are continuously on the decrease, and never on the increase, notwithstanding the increase of the wages of labour that has taken place, even in countries having a protective tariff. It is attributable and solely due to the fact that labour competes with labour in producing efficient methods of production. The only function that a Tariff performs in a country possessing one (we are here speaking of articles of utility only) is to confine the competition of labour with labour within the borders of the country concerned. This proposition, however, does not apply to countries having primitive conditions of civilisation, but only to countries having established civilisation, wealth, and industries. Another advantage to be derived from a tariff on articles of utility is that it ensures the distribution of a substantial portion of all wealth produced among the workers in the form of wages, which is only possible where continuous employment is assured. Such an advantage of course increases the purchasing power of the workers, and *ipso facto* increases the circulation of money.

In order to confirm the propositions herein stated, the following table of earnings and production just published by the United States Steel Corporation is quoted and it is highly instructive. This table is selected because the productions of the Company

have been protected during the period shown by a tariff. It will be seen that in the year 1902 the United States Steel Corporation earned almost as much on 8,197,000 tons as it did in 1913 on 12,374,000 tons. That the average wages paid have increased continuously from 1902 until 1913 (with the temporary exception of 1904). That notwithstanding the continuous increase of wages, costs of production have continuously decreased. That the average price of the finished product has been decreasing throughout the period. That the average profits earned by the Corporation per ton have gradually decreased.

Year.	Aver. Wage.	Aver. Prices.	Shipments. Tons.	Earn. Per Ton.	Total Net Earnings.
1902	$717	$39.96	8,197,000	$13.25	$133,308,714
1903	720	39.54	7,459,000	10.50	109,171,152
1904	677	34.89	6,793,000	8.51	73,176,522
1905	711	36.64	9,226,000	10.45	119,787,658
1906	730	39.29	10,578,000	11.90	156,624,273
1907	765	40.63	10,565,000	12.55	160,984,673
1908	729	38.17	6,207,000	12.06	91,847,710
1909	776	35.24	9,859,000	10.98	131,491,413
1910	801	36.11	10,734,000	10.86	141,054,754
1911	820	33.11	9,476,000	8.91	104,305,464
1912	859	33.54	12,506,000	6.67	108,174,672
1913	905	36.49	12,374,000	9.05	137,181,345
1914	905	29.41	8,500,000	6.00	75,000,000

American manufacturers of articles of utility do not hope to increase the price of their productions by the amount of the Tariff or any portion thereof, and the same argument applies to other manufacturers in other countries. But it can be assumed that in the purchase of tea the consumer must pay any import tax that is imposed, for the reason, as already stated, that labour cannot compete with Nature in Ceylon and other eastern countries in the production of tea; supply is limited to a season's crop.

It is the duty of the State, therefore, to ensure that no monoply is created in the supply of any given kind of natural material, and to ensure that no Tariff duty is imposed on the importation of it; but this statement, as already indicated, does not apply to material, advanced material, or other articles of utility in cases where it may be considered necessary. The latter proposition is safeguarded by the first.

There are certain wealthy Corporations which exist for the purpose of creating monopolies in what is herein termed natural material, but these should be broken up by the State, for they are a menace to cheap production; the community at large pay them huge profits to which they are not entitled. On the other hand, large Corporations which exist for the purpose of developing material, advanced material, or other articles of utility should be left alone, for it is impossible for them to create monopoly

prices and unreasonable profits, for the reason that labour competes with labour. Whatever profits may be earned by the latter group may be considered as being the reward of enterprise. If profits are continuously large, competition will set in and profits will become reduced in proportion to the extent of the competition.

It will, we hope, be seen that the questions we are discussing properly belong to and form part of ' First Principles of Production '; and we trust that the consideration now given to them may be instrumental in relegating their future development to the technologists. As we have already stated, viewed from the standpoint of industry, the problems of Free Trade and Tariffs are indivisible questions, and the problem as to whether one side or the other is of the most benefit to industry should not be left to the ordinary layman to decide, but to the leaders of industry in consultation with the Government.

THE INFLUENCE OF SCIENCE ON POLITICAL ECONOMY.

It is now necessary to study the relation of Science to Political Economy, and the strong but unseen influence it has had in exploding many of the theories now and formerly held by writers and politicians on the subject of Political Economy. The usual mistake that is made in this sphere of activity is the assumption that no change is possible in the factors which influence the views of Political Economists, as if any progress could be made without change. Politicians and writers should remember that Politics is one constant whirligig of change and progress, and that the conditions which prevail in one period of time will not necessarily prevail in another period of time. It is difficult to see how this is possible, considering that politicians on the one hand are constantly changing the conditions of life by legislation, and that men of Science on the other hand are constantly revealing unseen forces in the physical properties of matter, and constantly increasing our knowledge in the uses thereof. Free Traders, for example, hold up Adam Smith as the wiseacre of all the Political Economists, forgetting all the while that the extent of our Scientific know-

ledge in his time was infinitesimal as compared with the present time; this being the case, Smith's views should only be considered as being of value in his own period of time.

Those who advocate Protection on the other hand also seem to forget that Science and Scientific knowledge are the basis of all production, and that Protection, *per se*, will not in itself be sufficient as a means of increasing the productivity and efficiency of Industry. Take Russia, France or Spain for example; the Tariff duties in those countries have been about equal—if not higher—to those which prevailed in Germany, yet we have not found the same efficiency in production in the former countries as we find in the latter, where Science and Scientific methods prevail. It follows, therefore, that in any consideration which is given to the views of Political Economists, the basic working conditions in production—*i.e.*, Science and Education—should first of all be studied and compared with those which may prevail in other countries. This is necessary in view of the higher standard of knowledge which now prevails throughout the world in Science and Scientific Methods.

Industry has now come to be controlled by the technologist. In Germany, for example, there is one University-trained Chemist for every fifteen men engaged in the Chemical Industries, and in German Industry as a whole the ratio is one University-

trained Chemist for every forty men employed. In Great Britain we can make no comparison, for we have no Chemical Industries to speak of, but in British Industry as a whole it is estimated that there is only one University-trained Chemist for every five hundred men engaged in her industries.

As the basic working conditions, therefore, of Great Britain and Germany are not equal, irrespective of the economic position, the latter country could easily out-distance British Industry, and was, in fact, doing so prior to the declaration of war. As we have already indicated in a previous chapter, experience and knowledge are the prime factors in wealth production; all other considerations, relatively speaking, are of secondary importance.

For proof of these views let us examine the cause of the great rise of British Industry. In the Cotton and Woollen Industries, for instance, we find that in the latter part of the eighteenth century the inventions of Arkwright, Watt, Hargreaves, Crompton, and others were responsible for creating these industries in Great Britain on a substantial scale, and for giving it a practical monopoly of the manufacture of textile fabrics, and subsequently of other products almost as important, within twenty years of the discoveries being made. The point we have to consider is this : Was it the inventions, created by men having the requisite experience and knowledge, that established the textile industries in Lancashire and York-

shire, or was it Protection or Free Trade? We think unbiased people will give the credit to the inventions.

Lord Welby, in his thesis on "The Progress of the United Kingdom from the War of the French Revolution to 1913," gives the import of raw cotton and export of British-made cotton and woollen goods as follows in the period 1792 to 1853:

Cotton.

	Imports. Official.	Exports. British & Foreign. Official.*
	£	£
1792 ..	19,659,000	24,905,000
1815 ..	32,987,000	58,624,000
1853 ..	123,137,000	242,128,000

British and Irish produce	Export. Official.	Real.
	£	£
1815 ..	36,956,000	46,530,000
1853 ..	214,360,000	78,934,000

The record of the export of British-made cotton goods is interesting:—

	£	
1792	2,000,000,	Official value.
1815	22,000,000,	„ „
1853	131,000,000,	„ „

* In the days when these statistics were recorded the Government maintained a standard of value for comparative purposes which had no relation to the actual market value. But they are interesting from the point of view that even in those days costs of production *per se* continuously decreased.—J. T. P.

"The increase in real value was much smaller—from £25,000,000 in 1815 to £33,000,000 in 1853. The difference between volume and value was due to fall in cost of raw material, economy in manufacture, and fall in wages. The industry was fettered by bad laws. There was a tax on raw cotton, a tax on printed cotton goods made here, and a prohibitive tax on foreign-manufactured goods imported. They were all repealed before 1853.

McCulloch (1844) estimated the annual value of cotton goods made at £36,000,000, home consumption being two-fifths of the foreign trade.

The import of foreign-manufactured goods was trifling. In 1853, when all restrictions had been repealed, it was only about £1,000,000."

Wool.

"In 1700 we exported £3,000,000 of woollens. The export of home-grown wool was forbidden till 1824.

A duty was laid on foreign raw wool imported in 1802, and raised to the prohibitive rate of 6d. per lb. in 1819, hence little wool was imported from abroad till the duty was reduced and finally repealed (1844). It injured our manufacturers, who need a certain quality of foreign wool.

In 1853 the raw wool grown at home was estimated at 130,000,000 lb.; 82,000,000 lb. of raw wool was imported. The export of woollen manufactured goods rose from 5,500,000 lb. in 1792 to 7,500,000 lb.

in 1819, and (goods and yarn) 11,600,000 lb. in 1853.

Foreign woollen manufactures were practically excluded till 1823. They were then admitted at 20 per cent. *ad valorem*. The import in 1853 was £1,339,000.

We did not import raw wool from the Colonies before 1820. By 1850 Colonial wool was a chief factor in our trade. There is reason to think that there was increase in woollen goods consumed at home.

McCulloch estimated the total annual value of our wool industry at £4,000,000."

It should be noted that up to the period 1842-53 we had built up a large international trade, practically a monopoly, notwithstanding the tax which was imposed on the importation of the raw cotton and wool. The whole success of our industrial activity during the latter part of the eighteenth and for the most part of the nineteenth century was attributable to our practical monopoly of mechanical knowledge and inventions. A further great impetus was given to British Industry, however, after 1853 by the abolition of the import duties on raw or natural materials, in which were included cotton and wool, and the technical explanation for this is given in the previous article.

The following table * will show the extraordinary increase which took place in the importation of raw

* Lord Welby.

cotton in the period 1850-60, after the repeal of the import duty; the increase was over 100 per cent., but since 1860 the increase has been slightly over 68 per cent. only, which clearly shows the decline since then of the value of the monopoly positions created by the inventions mentioned above :—

	Raw Cotton, Imported.	Goods and Yarn, Exported.	Goods imported.
	£	£	£
1850 ..	561,146,000	28,258,000	341,000
1860 ..	1,140,600,000	52,012,000	685,000
1913 ..	1,916,654,000	127,162,000	12,250,000

In view of our monopoly of the mechanical inventions and the most scientific knowledge of producing cotton and woollen goods during the period 1792-1853, it mattered very little to anyone that the import duty on finished cotton and woollen goods was also abolished; it did not affect the position one way or the other during that period nor for some time afterwards. It will be seen, therefore that the basis of our economic system in the period under review was knowledge and scientific methods (at that time we possessed the most of each), although these have been considerably improved upon at the present time.

During the latter half of the nineteenth century the British iron and steel industries also received a great impetus from inventions, and these were as

follows :—(1) The Bessemer hot-air process; (2) the Siemens open-hearth process; (3) the Thomas and Gilchrist basic process, freeing the ore from phosphorus. A study of the statistics in this sphere of activity clearly indicates that a considerable increase in business began contemporaneously with the creation of these processes. The inventions had for their purpose the cheapening of finished iron, and naturally the demand for it considerably increased.

Then again we have had various processes introduced for the manufacture of high speed steel. The manufacture of high speed steel may not by itself appear to be a large industry, but its reflex action has been extraordinary. Owing to the introduction of this steel it has been possible to increase the speed and cutting power of machine tools. As a consequence of this, it was found necessary to enlarge these tools and strengthen them, in order that they should be able to stand the extra strain imposed on the machines by the higher speed and heavier cuts made possible.

This reflex process naturally brought about greater activity in the manufacture and design of machine tools, and owing to the decrease in costs of production so effected, greater activity was brought about in the manufacture of other kinds of machinery. Larger and more powerful designs were made possible at previous costs. In other words, cheap production in one sphere of activity cheapens

production in other spheres of activity, as it makes possible what in other circumstances might be impossible.

Another invention that has considerably influenced manufacture is Sir Charles A. Parsons' turbine engine. This invention has made possible the creation of the larger battleships we now have, and the larger mercantile ships now ploughing the ocean between Liverpool and New York. The foregoing inventions, therefore, have done more to increase the progress of human welfare than any political measure we know of.

This again proves the considerable service which Science can render to Industry, and also proves that any review of the economic position should not lose sight of the influence which improved methods or processes, resulting from the application of Science, have in the expansion of a particular industry, and the favourable reflex action which they may have on other industries.

Again in the twentieth century an excellent simile is to be found in the German chemical industries. Although Germany has afforded her chemical industries a measure of protection, she has irrespective of that built up a very large and lucrative international trade; she has, in fact, secured a monopoly in chemical manufactures in so far as Great Britain is concerned. In this respect the report on German trade for the year 1913, by Sir Francis Oppenheimer,

His Majesty's Commercial Attaché in Germany, is worth studying. On page 60 of the report he makes the following observation with regard to the chemical industry in Germany, namely :—' The prosperity of the German chemical industry is notorious. It yields higher profits than any other industry as a whole.' Various statistics follow which fully confirm this observation, and coming from such an authentic source, and considering the hopeless condition in which the British chemical industry has been placed, should remove any doubt which may linger in our minds on this subject. But the success of Germany in this and other spheres of activity can by no process of reasoning be attributable to her tariff system, but it is due to her system of national economics, which makes Science and scientific methods the basis of all her industries. Germany is emulating the system which prevailed in Great Britain in the latter part of the eighteenth and most of the nineteenth centuries, but which, by following false economic doctrines, we have allowed to lapse into decay.

Large profits are the reward of enterprise, but as soon as an industry has proved itself, competition sets in, and profits are reduced in proportion to the extent of the competition; and this applies equally to the originator of scientific processes or inventions, or at any rate to those who make them of commercial value. The function of a tariff on the importa-

tion of articles of utility is to confine the competition between labour and labour to the country imposing it—*i.e.*, to safeguard labour from the free competition of the labour of other countries who may use the inventions or processes so discovered as soon as their monopoly values cease to exist.

The general view held by the followers of the Cobdenite Theory of Trade is that they must repudiate any attempt to revert to the policy of Protection or the imposition of reciprocal restrictions upon the fullest freedom in the interchange of commodities, believing that whatever is of real utility and is best produced or manufactured in any one part of the world, is the best that every country should obtain at the lowest cost and in the readiest manner. This is a principle or theory which was developed by Adam Smith, and later by Cobden, and had a large measure of truth attached to it in Smith and Cobden's own period of time, by reason of the fact that empiricism was the controlling factor in production—*i.e.*, if Jones happened to be ill in the workshop, then production had to stop until Jones returned. But what is the general position to-day? Owing to the greater utilisation of Mathematics, Science, Chemistry, and Education in the great industries of the world, and particularly in America and Germany, there is no manufacture or article of utility that cannot be as well produced in America or Germany as in Great Britain. Science and

Scientific Methods have altered all systems and theories which have been held with regard to political economy, and as Mr. Illingworth very ably points out in his essay which appears later on : ' What a difference is found in reviewing the period from 1800 onwards. Throughout this time epoch-making inventions flash out as if from nowhere, improvement follows improvement with bewildering rapidity, and one wonders what it all means. The reason for this marked difference in the periods mentioned is, however, not hard to find, for the dawn of the nineteenth century witnessed the birth of Science as we now understand the meaning of this word.'

For the last sixty years we have had continuous quarrels over the merits or demerits of Free Trade and Protection, over the theories put forward by Adam Smith and John Stuart Mill, forgetting all the while that the greatest factor of all was lurking in the corner and waiting—Science.

It is for this reason that we believe that many of the theories formerly held by our political economists are unsound, and have, by the experience gained in process of time, proved to be fallacious. As we have said before, there is no finality : what is new to-day is old to-morrow. Similarly, any theoretical or practical views which we may hold to-day cannot be expected to remain effective in the next generation. We arrive at conclusions from the perspective of to-day, and the next generation must

likewise decide what may be best for themselves in the circumstances in which they may be placed.

In other words, conception and truth are synonymous; the conditions of life we live in to-day were created by our forefathers; the next generation will live in the working conditions which we may conceive to-day. Do we then realise our full responsibilities to the next generation? Shall we think?

FINANCE AND INDUSTRY.

We now propose to consider the relation of finance to industry. In the development of all kinds of natural materials to higher form utilities finance plays an important part.

The science of banking and the management of banks have undergone considerable changes during recent years, and such changes as have taken place have altered the relationship which formerly existed between bankers and those responsible for the management of industry.

The great amalgamations that have been effected have for the most part been effected for the purpose of securing greater control over the facilities granted to customers, to minimise competition, and to increase profits. Obviously they are not effected for philanthropic purposes. The policy adopted of keeping the deposits and capital of the banks in a liquid form has one great advantage, in that it provides greater security for depositors; but, on the other hand, it has limited the facilities which were previously at the disposal of those responsible for the management of industry, and consequently has placed them in a more disadvantageous position, especially in the case of small manufacturers of established repute.

The reverse of this policy has been adopted by the German banks; it is a coincidence that the German system of banking was adopted practically simultaneously with the new policy of British banks. We have, therefore, experienced this position, namely, a limitation of banking credits by British banks in so far as it concerns British industry, and an expansion of banking credits, in so far as it concerns German industry, by German banks assisted in some cases by the State. This fact alone has contributed largely to the considerable progress made by German industry in recent years as compared with British industry, and in considering the working conditions in which British industry operates the relative value of both systems should be examined both from the standpoint of the industrialist and the banker.

Let us take the German system first. The method employed by German banks in financing German industry has its advantages, and, of course, its disadvantages; but we think the advantages are greater than the disadvantages, viewed from the standpoint of German national interests. The fact remains that Germany has become a great nation; that German industry has, with success, supplied the funds with which the German Militarists have been able to conceive, and carry into execution, their plans for the Great War, in the best Bernhardian style. Had the German Army under von Kluck been

successful in its attack upon Paris, there would have been few indeed who would have condemned the German financial system, which enabled those responsible for the war of aggression to attempt it. The failure of the German military plans, however, must now bring about a crisis in German financial circles, but this does not in any way prejudice the statement of fact, that the extraordinary progress of Germany as a military, naval, and industrial Power in recent years is primarily due to the development of the financial system now in operation in Germany.

There are critics who say, of course, that the German system of financing industry, as a fundamental system, is unsound in principle, and is not one that could be applied with advantage in England. With this criticism we agree, but a modification of it is essential, and the reason will be seen later on. But the point we desire to emphasise is that the German system is (or was) not so unsound as many people imagine. We must remember that the science of production, management and distribution in Germany has, with the assistance of chemistry and applied science, been carried to a high state of perfection; that the German banks were therefore advancing money to firms who were able to compete on most favourable terms with manufacturers in other countries; that the risks assumed were not similar to those that would have been incurred by English banks acting in a similar manner.

In other words, so long as German industry as a whole was developing and progressing under the scientific methods of production she had adopted, and so long as no other nation sought to copy those methods, the German banks, in advancing loans upon liberal terms to German industry, were advancing money upon security of an unquestionable nature. Bear in mind that Germany has prospered, and that her financial and educational systems are responsible for it; and also that "nothing succeeds like success."

It should be noted that these observations are made upon the system prevailing in Germany prior to the declaration of war. As signs are not wanting that the leaders of British industry are at last realising the benefits to be realised from the application of science and scientific methods in production, the system employed by German banks in financing German industry may have to undergo modification at the conclusion of the war.

The policy of advancing loans, however, on the strength of prospective orders to individuals who do not possess established businesses is very unsound for the reason that costs of production during the first three years of the life of a business cannot be gauged with any degree of accuracy, even assuming the efficiency of the management to be good. The works have to be first of all created, then the right kind of machinery and labour has to be obtained, skilful

managers selected, and last, but not least, good managing directors must be secured. The whole organisation then has to carry out tests and experiments, and tune itself up to work cohesively and efficiently in production. As the cost of completing the organisation, therefore, cannot be gauged with any degree of accuracy, it will be seen that any bank advancing loans without security to establish a new industry is embarking upon business of a highly speculative nature.

This observation, however, does not apply to industries which have proved themselves, which pay dividends, and which desire loans for the purpose of carrying out extensions of their works. In all such cases, providing the management and the requisite working conditions are present, it is desirable from the standpoint of national welfare that they be encouraged, within reasonable limits.

It will now be seen, we hope, that it would not be reasonable to ask British banks to adopt, as a whole, the German system of financing industry; nor can British industry ask them to adopt any serious modification of it until it can demonstrate that it is prepared to place its methods upon as efficient a basis as the German system; until it is prepared to seek the co-operation of science in developing an improved system; and until it is prepared not to look upon the man of science as an academic person, but as one of the greatest forces industry can employ in reveal-

ing hidden secrets and in converting all by-products into new forms of wealth. Let it be understood that the adoption of this new policy would be as beneficial to labour as it would be to the manufacturer, inasmuch as it would open up to the worker the higher grades of employment which are now largely controlled by the workers in Germany and America.

On the other hand, if the leaders of British industry are prepared to reorganise their methods, it is only fair that they should expect a modification of British banking policy. There is a considerable danger in the present system of the absolute control of finance being placed in the hands of a few banks. The policy employed of keeping their capital and deposits in a liquid form is good for the depositor, but it is a menace to cheap production; for the reason that it encourages the manufacturers to bid for loans at high rates of interest, and considered from the standpoint of national industry, it is an undesirable practice.

R. H. Inglis Palgrave, in his book on 'Bank Rate and the Money Market,' a leading authority, has the following observation to make on this subject (p. 173) :—

'Those who are not conversant with the ways of many forms of business in this country, not large individually, but of great importance collectively, have no idea of the injurious effect which high rates of interest produce on the prosperity of these indus-

tries, and how rapidly heavy charges exhaust all possible profits. This is especially the case when those engaged in them are people with capitals comparatively small in proportion to the industries which they carry on.'

Again, on pages 52 and 53 in the same book, on the subject of the 'Growth of Bill Broking,' he makes the following further remarks :—

'When a banker requires a broker to repay him his "call-money," the only source from which the broker can obtain the requisite supply is from the Bank of England. The broker cannot expect to be able to obtain the sum in the open market, as all available resources there are, as a rule, employed up to the hilt. He therefore goes to the Bank of England, pledges what are virtually the banker's own bills, and thus is enabled to repay the banker. These bills may have but a very few days to run, but the broker cannot wait till they have matured. The banker must have his money, and the broker must find it. The broker has no reserve of unemployed money. He cannot afford to keep a reserve, as he allows interest at a higher rate than the banker does on all his deposits. Hence a demand for a comparatively small sum makes a stir, disproportionally large, in the money market.'

'This arrangement is not favourable to the quiet working of the money market. If the custom generally followed on the Continent prevailed in this

country, and bankers laid themselves out to discount freely for their customers, feeling at liberty to re-discount these bills whenever needed with the Bank of England, all the work of intermediaries would be saved and business would be on a sounder foundation. It is the custom of banks in foreign centres, as at Berlin, to re-discount thus habitually. The arrangement is a good one in many ways; it helps the central bank to keep in touch with the smaller business houses which surround it, and it enables those houses to carry on their business with perfect smoothness. The smaller banks in foreign business centres re-discount as a matter of course with the central bank, which is thus supplied with a large mass of perfectly dependable and rapidly maturing paper; but in London if it were known that a bank, even of the highest standing, habitually re-discounted with the Bank of England, it would at once be held to be "in extremis." In times of panic and peril such things, of course, have to be done, but in the ordinary way of business no London banker ever dreams of such a thing. The result is that while some London bankers discount, and to large sums, for their customers, others do not do so, and the customers, many of very high standing, go to the bill-brokers.'

'There are several causes which have led to this. In the first place the habit of a banker's discounting for his customers has been to a certain extent dis-

continued, if not dropped, while side by side with this the bill-broker has stepped in and found his opportunity. He can be depended on with certainty, while the reply of the customer's banker may be that he is "not discounting to-day." People do not like being met with this kind of answer from their bankers. They are far more independent than they were some twenty or thirty years since. They know that the brokers are always ready to discount, and will quote them the exact market price. The banker may not always follow this as closely as the broker. A very fractional difference nowadays is sufficient to send a man from his banker to the broker. The broker discounts the bills with money which belongs to the banker, who afterwards very probably receives the paper as "security bills" from the broker.'

'The London bankers have, to a great extent, built up the business of the bill-brokers by the course which they have taken of entrusting large sums to their care. The bankers have spared themselves some considerable labour by this, and though they have made a smaller profit from their transactions, they have gained by being able to devote a closer attention to their business generally. There are also, it must be remembered, the banks outside the business centre of the City, who hold large sums of money without possessing such means of employing them as the City banker does. Their requirements have also to be considered. The present

division of the work of our money market between bankers and bill-brokers appears likely to continue. While on the one hand there is an increasing tendency towards the exclusion of intermediaries in business, there is on the other a tendency almost equally strong towards specialisation. The bill-broker devotes his whole time and thought towards this subject; he knows not only the character and standing of the houses whose acceptances he is willing to take admirably well, but he becomes able to prognosticate very closely and with great shrewdness the future position of the money market, and arranges his dealings accordingly. He keeps his eye fixed not only on the position of affairs in this country, but on that in other countries as well. A knowledge of the course of the foreign exchanges is a great assistance to success in the business. But the practice of the bill-broker to work without a reserve necessarily tends to focus any large demand for money immediately on the Bank of England.'

We have endeavoured to be impartial in our criticism and to show the advantages and disadvantages in the British and German systems of financing industry; but the obvious conclusion one arrives at is this, that it is essential to establish a connecting link between British industry and British banking. The control of leading British banks is centred in London, and as London is the leading financial centre of the world, those responsible for

the management of the banks prefer to ignore the development of industry, and to employ their funds in short-dated loans, discounting of bills, bills of exchange, &c., &c., from which they can pick and choose in the London market. As this temptation will always be present, it is therefore necessary to consider ways and means. The banks control one of the essential materials required by industry, *i.e.*, finance, and the increasing power which is gradually being centred in a few banks must be checked. If the banks have the welfare of British industry at heart, they should be willing to consider the establishment of some medium, in co-operation with the leaders of industry, by which the difficulties outlined herein can be overcome. It is not desirable that the efficacy of the present banking system in Great Britain should be prejudiced, for, under that system, the banks have developed an international business of a very lucrative nature, but it is desirable that a more co-operative spirit and greater interest should be manifested in the welfare of national industry by those who control the financing of it. And this change of sentiment can only be effected if the leaders of industry and science will organise and co-operate for the purpose.

SCIENCE AND INDUSTRY.

To those who make a close study of economics there remains one great impression, uppermost of all—that, notwithstanding the conditions surrounding modern existence, no great living force can survive which is not permeated with the Christian doctrine. It is perhaps a strange thing to say in a materialistic age, but if a retrospective survey is taken of all the convulsive movements that have taken place in the past the conviction becomes more impressive. Pure religion and the earning of a living are all-pervading forces, and are inseparable; they are always at work, and can never be separated. Certain it is that if any attempt is made to separate them in any economic or political change, such change will never become a permanent feature in life.

Similarly, if a survey is taken of the working conditions which surround the forces of industry, one is forcibly brought to the conclusion that science and industry are also inseparable forces. If cheap production is a boon to humanity, scientific investigation is more so. If cheap production in one sphere of activity stimulates further production in other spheres of activity, scientific investigation in one sphere of activity must assist investigation in others, for the reason that it will make possible what in other circumstances might be impossible. In the close

application of science to industry Germany can be said to have taken the lead. At this moment it is, therefore, necessary that we should take stock of our present position. We should be candid, and recognise that British industry has not appreciated the advantages that could be derived from a close association with science as a living force. It may be due to the working conditions with which the State has surrounded industry, but whatever may be the cause, a change must be effected.

The lack of cohesion between science and industry in British industry is perhaps in no small measure due to the individualistic theory—that self-satisfied feeling brought about by the knowledge that our moral force is second to none; *i.e.*, the one has been a reflex of the other. But we must learn to disassociate industrial activity from the political, and closely examine the conditions surrounding the former.

In surveying the field of industrial activity we must for the future include scientific research. As already indicated, these two forces are inseparable—we have arrived at that period in the world's history where the two must be linked up definitively.

It is an accepted axiom in political economy that no man lives entirely, or even largely, unto himself; he can only do so with the co-operation of others. For this reason economics does not deal with individuals solely, but with individuals as part of a

larger body called society. If this proposition be accepted—and it must—we are forced to conclude that scientists must be co-opted in developing the progress of industry. They cannot live unto themselves, and the knowledge and experience which they gain should, as far as possible, be distributed through industry for the benefit and welfare of the community.

We have said that Germany has been the first to largely adopt this view, with considerable profit to herself commercially. A survey of the field of German industry will confirm it. Manufacturers in that country usually devote a fixed percentage of their profits to the maintenance of a well-equipped laboratory and an efficient staff of chemists. It does not matter whether it be in the metallurgical or the chemical sphere of activity—it is looked upon as a necessary part of the business. In consequence of this, we find that Germany has been responsible for the production of those delicate aniline dyes largely, if not wholly, used in the Lancashire cotton industry; also that Germany and America are responsible for the production of the Nernst lamp, automatic machine tools, Diesel engine, the flame arc lamp, the squirted tungsten lamp, the drawn wire tungsten lamp, the half-watt lamp, and various pharmaceutical products largely used, and greatly appreciated, in this country. They are essentially laboratory products—the result of a careful and

comprehensive study by trained chemists, physicists, and metallurgists. As a result of these scientific discoveries the German and American industries concerned have acquired considerable wealth for themselves, and all other countries desiring to avail themselves of the benefits of the discoveries must pay tribute to them in the form of royalties or a fixed cash payment. As a comparative study it is not creditable to ourselves, and whilst mankind must thank German industry for these benefits, let us see to it in the future that we participate in the work. It must be recognised that the moral effect upon purchasers in neutral markets is considerable. The knowledge that these inventions originate first in Germany must considerably assist in the distribution of German manufactures.

Mr. W. H. Dawson, a well-known authority on industrial conditions in Germany, has a very interesting article in the *Fortnightly Review*, November, 1914, on 'The Campaign Against German Trade,' and the following remarks of his on the relation of German science to German industry are very interesting:—'Probably the German is, on the whole, less practical and less bold in enterprise than the Englishman, but if he lacks in initiative he excels in diligence and application. Often he is twitted with an excessive love of system. But excess or deficiency of system

must be tried by results, and the German's fondness for system has certainly produced results in various directions which other nations have found inconvenient. His critical spirit encourages this predilection for methodical plans of action. For the German takes little for granted; he has no blind faith in the experience and methods of others; he will not embark upon a project until he is sure what he wants, and has satisfied himself as to the best means of attaining his end; but once clear as to his goal he makes for it, and as a rule he gets there.

'Very much of the success which he has attained in industry is directly attributable to the fact that his excellent systems of primary and secondary education are supplemented by provision for technical instruction and special scientific study and research. The German chemical industry, perhaps more than any other, owes its importance to science and scientific methods. It is estimated that in the chemical manufactories of Germany there is on an average one university-trained chemist to every forty workpeople—a ratio of science to labour probably equalled in no other country in the world. A recent German writer on this industry boasts that "empiricism has absolutely disappeared from present-day methods of production. We see at the head of our works men who would be an ornament to any chair of chemistry, surrounded by their staffs of thoroughly trained chemists. The larger manu-

factories have well-equipped and often model laboratories for scientific research, which it is a pleasure to work in. Nowhere is the alliance between science and technics so intimate as in Germany, and no one doubts that the pre-eminence of the German chemical industry is due to this fact."

'The truth is that while in this country science is still barely tolerated, in Germany it is valued and respected as the natural ally of industry. Science—in other words, the sum of knowledge and observation co-ordinated and systematised—is to the alert German the dynamo from which issues the energy which has enabled him to conquer matter, build up and sustain great industrial enterprises, invade the markets of the world, and assert for himself, with an almost dramatic rapidity, an honourable and a leading place in the arena of international trade rivalry.

'In the application of science to industry there is never cessation or slackening. When at the centenary celebration of the Berlin University in November, 1910, the Emperor advocated the establishment of the school of research, half a million pounds were placed at his disposal for the purpose before the meeting dispersed. Under this scheme a research institute for chemistry, physical chemistry, and electro-chemistry has already been established, and other institutes are to be established in different parts of the country. One of these will

be placed in the centre of the Rhenish-Westphalian colliery industry, and it will be devoted exclusively to research in connection with coal and its derivatives.

'"There will be opened up to the institute," so runs an official *communiqué*, "a sphere of work which not only claims a high scientific interest, but which will prove of conspicuous importance for the districts named and their industries, and in particular for the colliery and smelting industries, and the undertakings allied thereto. From research of the kind epoch-making results can be expected only after systematic work carried on for some years, and this can be done only in a purely scientific institute equipped with all the aids of modern technology. An institution of this kind can alone apply itself with any prospect of success to problems the solution of which would add greatly to the resources of civilisation."

'Perhaps the most significant part of the official statement is the intimation that "the deep interest of industrialists in the project referred to may be concluded from the fact that a number of the larger works in the colliery, smelting, and allied industries of Rhineland and Westphalia have guaranteed yearly contributions, which will cover the cost of carrying on the institute for many years to come. These works will co-operate in the management of the institute." It may be added that the town of

Mülheim-on-the-Ruhr, where the institute will be established, will provide the necessary buildings free of cost.'

It should not be assumed that we have made no attempt to improve our position; we can turn to the work now being done by the Imperial Institute as an example. The research laboratories and workrooms of the Imperial Institute have been established in order to provide for the investigation of new or little known natural products from new sources, with a view to their utilisation in commerce. The laboratories also furnish trustworthy scientific and technical advice on matters connected with the agriculture, trade, and industries of the countries constituting the British Empire. Materials investigated in the research laboratories are afterwards submitted to further technical trials by manufacturers and other experts, and, finally, are commercially valued. Our only fault lies in failing to achieve cohesive action and in failing to appreciate the good work which leading chemists and metallurgists have been doing in this country for us: they have sought for their opportunities, but British industry has refused it to them.

For the next generation or two the basis of Imperial economics will be the importation and utilisation in British industry of our requirements in natural materials from our Dominions and Colonies. We have been dependent upon Germany

for a very large part of our materials; we have allowed Germany to take certain of our industries by the methods previously indicated. To restore the industries we have lost through *laissez faire* must be our first objective, but this can only be accomplished with the co-operation of the Dominions and Colonial Governments. The laboratory of the Imperial Institute must also be utilised in conducting the requisite experiments; but if all this is to be accomplished, the forces of industry must be organised on a practical working basis. The natural tendencies of industry must be changed gradually to new and safe channels, and in view of what the Dominions and Colonies have done for us in this great war, it is our obvious duty to develop the business with them. Certain it is that we cannot expect them to purchase more of our finished products unless we increase their purchasing power correspondingly. It will be seen, therefore, that scientific research and the importation of natural materials from our Dominions and Colonies constitute the basis of Imperial economics, partly of National economics, and that all concerned should adapt themselves to the changed conditions.

THE CO-OPERATION OF SCIENCE AND INDUSTRY.

By S. Roy Illingworth, A.R.C.Sc., A.I.C., B.Sc.Lond.

I.

Science in its broadest sense may be defined as exact knowledge. The significance of the use of the word ' exact ' cannot be too firmly impressed upon the mind of the non-scientific person, for upon a true appreciation of the aims and scope of Science depends the answer to the question as to what part we should expect the scientist to play in industrial concerns. Only the study of Science itself can bring home to one the distinction that should be made between Knowledge in its ordinary sense and Science (as defined above), but perhaps a sketch of the growth of a ' science ' out of the ' knowledge ' of the ancients may assist the reader to grasp the distinction, and for this purpose we may select the science of Chemistry and trace its evolution from the Alchemy of the past, but it should be distinctly understood that the same reasoning applies to all branches of Science.

The pioneers of Chemistry were the old sages and philosophers known as the Alchemists. Their

labours were devoted to the study of the properties and transmutations of substances of common occurrence. This work they carried on incidentally with attempts to discover the Philosopher's Stone, and the Elixir Vitæ, that would enable them to get rich quickly, and then live to enjoy their wealth without suffering from gout or from an impaired digestion. Their work was haphazard, and every substance was treated in an individual manner. They amassed many facts—that is, they gained knowledge—but they made few attempts to explain their observations, nor were they able to fathom the forces at play causing the observed changes. This early school of Chemists gave way to another one, to whom explanation of phenomena was the essential feature, but they erred in being too fond of theorising on grounds hardly supported by experimental evidence. It was not until the end of the eighteenth century that Chemistry became a Science. This was due to the application of methods of measurement to experimental work, which, in conjunction with the correlation of the observed facts, has brought to light the truth that all chemical phenomena can be grouped into a definite system. The development of this essentially scientific method of investigation has laid bare the foundation of Chemistry upon which succeeding generations of Chemists have reared the noble edifice of the modern Science. The fundamental object in rearing this building has been,

and still is, carefully to determine the relationship existing between any individual part and the rest of the structure, and to weave cause and effect into an orderly chain. So systematically and accurately has this edifice been built that phenomena can now be explained and forecast without recourse to laborious experiment. It is this marshalling of facts, this measurement and the resulting deductions, that distinguish Science from Knowledge, as we ordinarily understand that term. The transcendental importance of laws and of correlated knowledge to a science may be compared to the means of communication existing in any country to a traveller therein. For instance, the traveller may wish to travel from one place to another, but knows not what route to take, what the proposed destination is like, where to stay, &c. He is possessed of no exact knowledge, but by consulting the map of the country, making inquiries of an expert in travel, &c., he is able to accomplish his purpose with the best results. The traveller in the land of Science is in an analogous position. Here, for instance, in the country of Chemistry we find the expert to guide our operations is the Chemist. The map of the whole community of substances in Nature is set out in his mind; a map built up by studying the work of the Chemists of the past. He knows the intimate relationships of substances, their nature and their use. He can advise the best means of passing from one to another, when to per-

form the operations, and how most easily to perform them. Summing up, we may say Science is that highest form of Knowledge in which the relationship of all known facts has been ascertained, traced, and reduced to laws, these laws enabling the scientist to forecast the action of substances, forces, &c., upon other substances and forces. Still further, they enable him to utilise forces and substances to produce desired effects.

The Scientist is naturally well versed in these laws, laws that fulfil both quantitative and qualitative functions. His mental attitude to the hundred and one forms of matter is orderly and logical. His brain is like the cinematograph film; one by one he has stored therein the various impressions that, following one another, produce the whole sequence of events in any cycle of operations. At any time he can begin to think from a particular point in the cycle, and follow up any observed phenomena to their logical conclusion. Continuing the simile of the railway service, we may compare the true scientific brain to the railway time-table. By consulting the latter anyone can ascertain when to start from a certain place upon a particular journey. In the same way the Scientist, by virtue of his orderly intellect, knows when and how to put into operation a certain process. This orderliness and breadth of view, which can only be attained by scientific study, cannot be too firmly impressed upon the non-

scientific mind. It permits of the Scientist coming to valid conclusions, or, as some may say, ' prophesying ' the results to be obtained in any cycle of operations. The Scientist has brought to light and studied the effects of the forces around him. He has come to understand all kinds of matter and the methods of influencing them. In a word, he studies all phases, forces, and materials of Nature.

Industry, on the other hand, is the art of producing from one form of substance other forms for which there is a demand. Under existing circumstances this production takes place in such a manner that the maximum efficiency is rarely, if ever, attained. Maximum efficiency requires that in the process of manufacture the least cost shall be incurred and the best article commensurate with cost produced. To dwell on the aims of Industry would be futile. Suffice it to say that its fundamental activity is concerned with the changing of the forms of matter for pecuniary gain. Does this not appear to be closely interwoven with the aims of Chemistry? What answer should be given to the query, ' Have Science and Industry any common ground upon which the two could work together for mutual benefit? '

We have seen in the earlier paragraphs that the modern Chemist is concerned with the methods of changing one form of substance into another. Remember he is not concerned with these changes

in the ' Cookery Book ' or empirical manner; his sole aim is not to add so much of this, a drop of that, heat for so long, and attain the desired result. His concern in the operations involved is far deeper. He comprehends the forces underlying these changes, the machine, so to speak, determining the transmutations. His position towards matter is analogous to that of the medical man towards the human body. The Chemist can ' prescribe ' for matter, remedy many defects in its nature, and determine the changes it can undergo. He is not a magician or a quack, but can use his scientific *knowledge*, knowledge built up by the best brains of the past, to cause and direct the production of one form of matter from another. Here lies the common ground upon which the Chemist and the manufacturer can meet and *co-operate*. The manufacturer should be conversant with Science, he should invoke its aid to advance his interests. In England at the present day the co-operation between the manufacturer and the Chemist is fitful and uncertain. Our industrial methods are frequently obsolete; they undergo little or no improvement, and we have very few Chemists engaged upon Research Work. Many of the processes of manufacture conducted in this country are wholly empirical, and they are not under the control of people who comprehend the principles governing the manufacturing operations. Industry, like everything else,

must improve along evolutionary lines. It is imperative for our national industrial stability that we be careful to see we are not left behind in this evolution, wherein the law of the survival of the fittest will operate. In naval and military matters we are jealous of foreign countries and of the progress they make. Do we exercise the same degree of jealousy or expend the same amount of energy in advancing our methods of production? We do not. We are behind our foreign competitors, and the longer we are content to remain as we are, the harder it will be to make up leeway. In our days all improvements and new inventions emanate from abroad. Many of the industries that arose out of the research and scientific attainment of our own countrymen have passed into foreign hands. The reason is evident: in these countries Science and Industry work hand in hand. Our manufacturers are already feeling the effects of this foreign competition. Articles in the manufacture of which they held pride of place are being turned out abroad superior in quality to those of British make. Competition is becoming keener year by year, and fractional parts of a penny saved in the cost of production will become increasingly important. Waste in any process must be cut down, and from it new commodities must be evolved. How can this be done? By following on the lines of our rivals and bringing Science more fully into our factories. In a word, Science and Industry must com-

bine. Proof of the truth of the above statements and of the urgency of the need of such Combination and Co-operation will be given in subsequent chapters.

II.

The benefits that Science has given to the world are manifold. Volumes would be required to do anything like justice to such a colossal subject as the effect of Science upon civilisation, and its history would constitute one of the most fascinating romances ever written.

Cast your thoughts back to the state of things existing at the close of the eighteenth century, and contrast it with the present state of affairs. Instead of having gone back a hundred years, you will feel that by contrast you have gone back a thousand years and more. It is hard to single out any prominent innovation in the period previous to 1800, for what progress was made during this time was slow and the result of the accumulation of years. What a difference is found in reviewing the period from 1800 onwards. Throughout this time epoch-making inventions flash out as if from nowhere, improvement follows improvement with bewildering rapidity, and one wonders what it all means. The reason for this marked difference in the periods mentioned is, however, not hard to find, for the dawn of the nineteenth century witnessed the birth of Science as we now understand the meaning of

this word. It was this new force, this new outlook on our surroundings, that has brought about the countless changes seen in all walks of life. What do we find in briefly surveying the last century? We find new colours flashing into view. Communication in every form is more intimate, distance appears to vanish, our methods of transit becoming weird and superhuman. Of a truth Science has put a girdle round the earth in forty minutes. Our homes are better lighted, and our streets are no longer the nightly resort of footpads, for Science, in bestowing the boon of efficient lighting and rapid communication, has rendered the task of the evil-doer far more difficult. Science has improved our health through the progress of medicine and hygiene. Science, like a magician's wand, has transformed our very existence, our diet, and our habits.

The triumph of Science entirely surrounds us in our everyday life, and her productions have become such deep-rooted necessities that we hardly realise the extent of the stupendous debt we owe to our ever-generous benefactor. Business could never have expanded to its present size had not Science placed a thousand and one facilities in the hands of Commerce. Those business people who decry Science as a useless factor in Commerce have only to reflect for a moment to find their telephones, telegrams, means of rapid transit on land and by sea, cheap stationery, lighting, in fact their very existence is the outcome

of Science! Without it, it would be impossible to carry on a minute fraction of the world's present transactions. Imagine trying to conduct business if letters from London still took three weeks to reach Glasgow, if goods took months and months to reach America, and if there were no direct communication between inland towns, let alone between continents. Now it is possible to cable to nearly any part of the world and to receive a reply the same day. Distance has vanished in comparison with the past, and time has been prolonged, because so much more can now be done in a given time than could be done even a decade ago. And it is Science that has to be thanked for it all, since every one of these time-saving, labour-saving devices, means of rapid communication and transport, &c., is the culmination of ceaseless endeavours of generations of Scientists. They are not the outcome of haphazard leaps into the dark and 'lucky shots.' They have arisen by the subtle method of experiment and theory, theory and experiment, of which none but those of scientific training are capable. That academic refinement so scoffed at by certain ignorant people is the very essence of progress and of the achievements of modern civilisation. The most certain way of expanding our manufacturing activities by producing new products, improving existing ones, and attaining greater efficiency in our factories, is to realise this dependence of Industry on Science, and to

employ the technologist to a larger extent in the factory.

The Scientist is for ever trying to harness the forces and develop the materials of Nature for man's use. Let us trace the fascinating steps by which the Chemist has built up new industries, and see how he has seized upon the waste products arising at one stage to build up yet newer and more lucrative processes. To illustrate this process of what may be termed the evolutionary uses of Nature's storehouse, we will turn our attention to coal, and see what part this commodity plays in Industry.

Coal, as everyone knows, is the product of the fossilised remains of forests that grew ages ago. We in Great Britain are almost entirely dependent upon it for our national welfare, and we should look to it that we make the best use of our present supply and use every endeavour to develop our coal-fields. The first use to which coal was applied was that of supplying heat for domestic purposes. Coal as a domestic fuel was employed for centuries before its utility in manufacturing processes was discovered. Subsequently it was productively employed, first in the raw state, and later in the form of coke, in the metallurgical industries, and particularly for the manufacture of iron. Apart from these applications, the use of coal as a raw material proper was not introduced on an industrial scale before the earlier part of last century, when it was employed in the

production of illuminating gas. The products arising from the distillation of coal for this purpose are of three kinds: (*a*) the gaseous products; (*b*) the liquid products, consisting of coal tar and ammonia liquor; and (*c*) the residue, consisting of coke. For many years after the birth of this industry the only useful products arising from it were the gas and the coke. The liquid products were regarded as a necessary evil of the process for which no commercial use could be found. Through the discoveries arising from the patient endeavours of many chemists these liquors, at one time regarded as the bugbear of the industry, are now looked upon as most valuable products. The coal-tar liquors consist of a complex mixture of what are termed hydrocarbons, accompanied by compounds belonging to the same chemical class as carbolic acid. The tar distillers separate this complex into its constituents, and produce the hydrocarbons benzol, toluol, xylols, naphthalene, &c., as well as the carbolic acids, creosote, pitch, &c. Each of these products is much sought after in commerce, for chemical research has found for each and all of them a lucrative commercial use. Thus early in this brief survey of the industrial uses of coal do we come across examples of how Science forces out new shoots from the tree of industry, and we shall see how these new shoots rapidly develop into strong branches, from which Science forces out yet again fresh shoots. Let us turn our attention to some of

these coal-tar products, and see to what uses they are applied.

Has the reader ever marvelled at the endless range of shades and colours that confronts him in, for example, the drapery stores? Has he ever chanced to inquire into their origin? What a romance, what a triumph of Science is portrayed by this endless range of colour. Years ago who would have dreamt that such colours would arise from that noxious oily liquid resulting from the manufacture of gas? To read the romance of the coal-tar dyes must bring a blush of shame to the cheeks of all Englishmen, for they will realise what the conservative prejudice of our forefathers has lost to this country. The way to this vast and lucrative industry of the manufacture of dyes from coal tar was shown by the researches of our fellow-countryman the late Sir W. Perkin. Alas! Englishmen are not reaping the rich harvest of this industry, for the mistrust of Science so typical of many of our commercial men would not allow of their supporting the infant indutry that has now grown to such gigantic proportions under the fostering scientific care of Germany. To-day practically all dyes are built up from coal-tar products by chemical processes. One by one the natural colours have been imitated, and dyes of vegetable and animal origin fallen into desuetude. This is not all, for slowly but surely the Chemist has built up the complex science of the dyestuffs that

permit of his producing the most subtle differences in shade and a range of colour undreamt of in the days of natural dyestuffs.

The value of the imports of coal-tar dyes into this country has steadily risen from £708,797 in 1899 to £1,818,575 in 1912, the bulk of these dyes being derived from Germany. On the other hand, the exports, which presumably refer to home-made products, have remained almost stationary, and amounted in 1912 to a value of £204,475.

It should not, however, be forgotten that millions of pounds have been expended in experiment; failures there have been, but the Germans realise the value of Science, and to them these failures have been but stepping-stones to new industries; their faith never falters. This faith in Science has given them the monopoly of the dyestuff industry, and a proud position in the commercial markets of the world. What would some of our commercial men think of an expenditure of three-quarters of a million pounds in experiment? One feels that many of them would have abandoned the endeavour long before such a sum had been spent. Not so the great German firm of Baeyer, who spent this amount before they were able to manufacture indigo on a commercial scale. Their process turned naphthalene, once a waste product and the bugbear of the tar distillers, into a valuable raw material. This discovery affected our Indian Empire very severely, for

prior to it nearly all indigo came from the indigo plantations in Bengal, but now this natural industry is practically dead, and the great bulk of indigo comes from Germany. Whilst speaking about indigo one cannot help mentioning an example of ignorant prejudice exhibited by some of our dyers. These gentlemen, when the synthetic product was first introduced, did not like to use it because the dye liquors made from it lacked a smell peculiar to the natural variety. They did not realise that this artificial variety was constant in composition, and, compared with the variable natural product, gave more certain results. The coal-tar dyes are not the only products obtained from the liquid products derived from the distillation of coal, for each and all of the products have other uses. The tar acids are extensively used as disinfectants. Carbolic acid is the parent substance of a whole host of drugs, food preservatives, and medicines. Salicylic acid, salol, and aspirin, frequently used for the last purpose, have as their parent this coal-tar product. Creosote is used extensively as a timber preserver, and prolongs the life of many structures. Pitch, the product remaining after removal of the hydrocarbons and tar acids, has a host of uses, such as making damp-proof walls, asphalt, &c. Tar finds many applications, and is especially used nowadays for making dustless roads. Perhaps in the future these coal-tar products will play a great part in our power

supply, for already they are used to some extent as a liquid fuel, and such uses will no doubt increase.

Thus far we have dealt in a very cursory manner with the oily portion of the gas liquors. The other portion, known as the ammonia liquors, is also a very valuable product. The main constituent of this liquid is, as its name implies, ammonia. This body is liberated from it and converted in various salts of ammonium. Chief amongst these is ammonium sulphate, which is extensively used as a fertiliser, and hence we reap material benefit from these liquors in the shape of greater crops and a better food supply. Not only does our food supply benefit in this manner, but upon the use of ammonia is based the principle of cold storage. This cold storage not only permits of fresher food, but also allows this country to draw its food supplies from far-distant lands, and to enjoy fruits and perishable goods not thought of years ago. The benefits of cold storage have been derived from the combined efforts of the chemist and of the engineer, who have jointly perfected a machine which causes ammonia to evaporate at one point with the production of great cold, and to condense back at another point to its former state in readiness for passing through the cycle of changes once again. It is by this evaporation of ammonia that most of the ice to-day is made. Like many other processes, the process of cold storage is changing; solid carbon dioxide is used on board ship in place of ammonia,

and a further development is the use of formalin as an antiseptic preservative, but in whatever direction change ensues, Science shows the way.

The gaseous products of the gas industry have engaged the attention of the Scientist, for he is never content, but is for ever striving after improvement. Who to-day would tolerate the evil-smelling gas of the past? This evil smell was due to the presence of sulphur compounds, and the Chemist devised methods to remove them. This removal was effected by passing the gas through large chambers filled with oxide of iron or lime. Revivification of the iron oxide by exposure to air and repeated use of the revivified material results in it ultimately retaining upwards of fifty per cent. of its weight of sulphur. The material thus produced is now the source from which a considerable amount of our sulphuric acid is derived. This example shows how the Scientist tackles his problems and converts a defect into a blessing. There are yet further valuable products removed from the coal gas, namely, the poisonous cyanogen bodies it contains. Their removal is effected by chemical means whereby the cyanogen is recovered as potassium cyanide and utilised for the extraction of gold from low-grade quartz. This does not by any means exhaust the history of the results of Science applied to coal gas. There is, for instance, another important improvement to be mentioned, the incandescent mantle. Contrast the

old form of light with that we now enjoy, and remember that it is Von Welsbach, the Austrian Scientist, who has to be thanked for the improvement. This innovation caused Scientists to turn their attention to what they termed the rare earths, and to open up a commercial use for them.

The above paragraphs have been written to show how Science has affected what may be termed the ' coal ' industry. Even this brief survey must cause one to realise the far-reaching effects of Applied Science upon industrial operations and commercial progress.

It should be remembered that this is but one page from the voluminous history that could be written on the achievements of Applied Science. Does it or does it not suggest sufficient proof of the statement that Science can help Industry, and should be working in co-operation with her? It should be remembered, too, that many of these innovations and new industries arose in the first place from the labours of the ' academic ' men—that is, of men not engaged in actual commercial work, but in the teaching of Science. If so much has been accomplished along such lines in the past, how much greater improvement can we expect if every factory had its scientific expert, ready to tackle any problem, and to seize upon the chance of utilising waste material? Everything points to much good accruing. Chances of utilising waste may have come, but they

have not always materialised, because the individual to whom the opportunity occurred has not had sufficient scientific knowledge of his subject or breadth of view to realise the importance of the occurrence.

Chance has played a large part in the discovery of new processes and new industries, but always in conjunction with the scientific development of the opportunity offered. Thus when the late Sir William Perkin discovered the first coal-tar dyes, he was really working on the constitution of quinine, but his investigation took an unexpected turn, which he seized upon, investigated, and developed, thus initiating the industry of the coal-tar dyes. Again, the commercial realisation of the manufacture of indigo arose from the breaking of a thermometer. One stage in the process under investigation demanded the oxidation of naphthalene to phthalic acid. It had been discovered that sulphuric acid would effect the oxidation, but only to a limited extent. When the thermometer broke it was found that the process had been completed. Here was the chance, and the Scientists conducting the experiment made use of it, for they elucidated the reason for the complete oxidation, and found that the mercury from the thermometer was the cause.

Chance alone is of no use, however; what is needed is the man on the spot who can avail himself of it. The Scientist is the man required; his training and consequent elasticity of mind never allow

him to let anything escape unnoticed, uninvestigated. Just as a blind man could not be expected to discover a goldfield, even if he were sitting down on an outcrop of gold-bearing quartz, neither can a ' rule-of-thumb ' man be expected to realise the possibilities of some occurrence in the factory. What is needed is the man possessed of scientific insight. Other countries employ such men in their works and reap the benefit. We are behind, and must make up the leeway. Let us consider first what our foreign rivals are doing with their Scientists.

III.

The Englishman was the pioneer in Industry, and for many years enjoyed the advantage of his early start. The world was his market, and English goods went everywhere without commercial opposition. Time has changed this state of affairs, and the English manufacturer has now to compete with those of other countries both in the home and in the foreign markets. Already we hear the cry of ruined industries, and some people are too prone to decry us as a ' scrap-heap ' nation. Such persons should view this question of foreign competition from another standpoint, namely, by comparing the methods of production at home with those in vogue in other countries.

The last chapter gave a brief outline of the colossal extent to which the manufacture of dye-

stuffs has grown in Germany. That this growth is due to the application of Science to Industry is beyond question. A visit to one of these large dye factories would open the eyes of the man who decries Applied Science. On such a visit he would meet the Scientist at every turn. In the laboratories he would find the Chemist engaged in various capacities. Men of University training would be found applying their knowledge to the control of works processes. Such men would be found carrying out analyses of the raw materials, checking at every stage the multiplicity of the works operations, and finally making sure that the finished product was up to standard. Not only would he find the University man acting as ' policeman ' to the works, and keeping it on its best behaviour, but he would find him *acting* in a *directive capacity* (as a *research chemist*), investigating methods, producing new products, improving old processes, and cutting down the cost of production. It is this application of Science that has done so much towards building up the present industrial position of Germany. This probing into the fundamental principles of a process, whereby a thorough working knowledge is attained, is the secret of all innovations. Working along these lines, failures in manufacture are rare, spoilt batches to be sold at a loss are few. Customers' complaints are seldom heard, for every batch of goods is tested before dispatch, with the resulting boon of uniformity in

quality, and uniformity in the cost of production. In Germany everything is manufactured under the eagle eyes of trained Scientists; works managers, and often works foremen, are University, Polytechnic, or High School men. Nothing happens in the works that escapes attention; failures, when they do occur, are investigated, improvements made, and a recurrence of the trouble prevented. This one instance is typical of the industrial methods of Germany. In one of her large dyeworks one hundred and fifty trained Scientists are employed, all of them University men. The members of this staff engaged upon research work turn out about three hundred new dyes a year, only a fraction of which become commercial articles. Yet this procedure pays, and pays well. Waste material in Germany is rare compared with this country, for everything is experimented upon with a view to finding a commercial outlet for it. An object-lesson for the Englishman is furnished by the large quantity of old ' tin cans ' imported into Germany from this country. In this country they are regarded as waste, and disposed of, for the most part, for next to nothing. To the German they are the raw material of an industry. Stripped of solder and paint, these waste ' tins ' are so treated that the tin coating is converted into tin salts, and the residual iron is utilised as scrap in steelworks. These tin salts are in all probability exported back to our dyers, and used in conjunction

with Continental-made dyes to produce, maybe, the parti-coloured bunting that the loyal Englishman proudly displays in honour of some important occasion. Another example reflecting the different attitude of the English manufacturer compared with that of his Continental rival is to be found in the case of sugar refining. An important refinery in this country is content to turn its residues of molasses into the sewer. Not so the Continental firms : they convert it into potassium carbonate and betaine of pharmaceutical value and into cyanides. These cyanides, much used in gold extraction, are also extracted from the ' schlempe ' of the Continental brewer, whereas our brewers pay no heed to this method of utilising their waste.

Space forbids further mention of the scientific developments that have led to industrial innovations. ' Made in Germany ' is like a red rag to a bull with some Englishmen, but if they would probe deeper into the reasons for the monopoly, they would find the ' tag ' should read ' Made in Scientific Germany.'

Let us see what the U.S.A. are doing along scientific lines. We find the Americans are invoking the aid of Science in every possible way; more especially do we find Science applied to the development of her national resources. State and national bureaux have been established for every conceivable object, from Agriculture to Emigration. A brief

description of the methods of the Agricultural Bureau will give some idea of the far-reaching influence of these institutions. In the first place, there is the National Bureau in Washington, which is the headquarters of the large staff engaged on the development of the whole agricultural area of the States. In addition to this central organisation many of the individual States have their own Agricultural Colleges that combine the function of training agricultural experts with that of advisers to the local farmers. These institutions are the guiding hand in agricultural affairs; to them the farmer turns in time of difficulty. Thus he may send his soil to have it analysed and reported upon. He will be given information as to what manures to use in its improvement, for what crops it is suitable, and he will even be supplied with the best seed for these crops. He can always turn to these institutions in cases of blight or failure of crops, well knowing that he will receive the best possible advice. In some cases, if needs be, an expert will be sent to his farm to investigate the trouble on the spot. That good has attended this comprehensive scheme goes without saying. For instance, at one time the yield of wheat per acre of certain districts in California had fallen very much below the average. The Berkeley University took the matter in hand, and in four years the yield was increased tenfold. Another proof of the activity of this University is furnished by its methods

of taking, so to speak, the college to the farmer's doorstep. Every year the staff tours the State in a train specially equipped with lecture rooms, demonstration rooms, a museum, &c., making stops *en route* in order to deliver lectures and to exhibit the latest developments in farm appliances.

Although the organisation of expert advice and assistance to farmers and other agriculturalists is not organised in this country to the extent that it is in America, there are a good many experimental stations and colleges where advice can be obtained and analyses supplied at exceedingly reasonable rates. In this connection, the experimental stations established at Rothamsted by Sir J. B. Lawes and at Woburn by the Royal Agricultural Society may be mentioned. In the past few years we have seen the establishment of a special Parliamentary Grant for Agricultural Development, part of which grant is devoted to the training of a staff of advisers in agricultural matters. Let us hope this is the commencement of a vast scheme to establish our industries upon a sound scientific basis.

To-day all new processes, inventions, and developments emanate from abroad. In the past we could point to many epoch-making inventions as of solely British origin, but what outstanding innovations of the last twenty years lie to our credit? Motor-cars, wireless telegraphy, aeroplanes, the Diesel type of internal-combustion engine, &c., all

have their origin abroad. Turn where you will, look into the running of any concern you like, and you will find that the foreign rivals of this country are ahead of us in applying Science to Industry. The originators of our industries were men of scientific outlook, and never ceased experimenting to perfect their processes. For many years these industries had no serious foreign competition, but now all is changed, and we must alter our methods to cope with the change.

Contrast the current methods of most of our industries with those in operation in Germany, Austria, U.S.A., &c. On the one hand we have empiricism, rule of thumb, and a conservative contentment with the old order of things; on the other we have ceaseless endeavour along scientific lines to produce improvement and greater efficiency. We know the English manufacturer desires improvement, but in many cases he goes to work along the lines of trial and error on a large scale. His attempts at improvement are often leaps into the dark, spasmodic and unscientific. In many cases these attempts have only been made under the stimulus of the loss of trade consequent upon the appearance on the market of an article superior to his own. There is little endeavour to get ahead and *keep there* by means of systematic research work. We also are behind the times in the utilisation of the routine man. Works processes are not adequately checked,

and finished products are not regularly maintained at a uniform quality. As one who has had to deal with the supply of goods to conform with a rigid specification, the author can speak from experience. The tender samples submitted from a large number of firms, and professing to be of definite quality, are a profound object-lesson. Some of these samples would be much above the requirements, others would be below, a very few would conform closely to specification. Then, again, the deliveries will vary greatly. One delivery would be just right, another would be too high, and one day a supply would fall below the limits. One could realise the empirical methods of manufacture in operation and the lack of scientific control. How much a Chemist would save these firms it is impossible to say, but the variations in quantity of an expensive ingredient must represent considerable variation in profit.

Adulteration is very rife to-day. Candidly, I believe there is more opportunity in this country for a Chemist to ' do ' the manufacturer than there is for him to assist him. This represents laxity in testing on the manufacturer's part, and until he alters his ways he will be ' done.'

The business man has not the time to occupy himself with scientific problems, nor has he the knowledge to solve them, so naturally he cannot appreciate the usefulness of Science unless that usefulness is drilled into him. It is for the Scientist to

emphasise this aspect of his subject to the business man, as there is no doubt the latter will, in the majority of cases, lend a willing ear to any scheme for enlarging his profits. Of course there are some who will not, because they still regard Science as a harmless pastime for old men and young boys, a ' hobby ' that serves no useful purpose. The two extremes in the rival camps—that is, the Scientist with a lofty contempt for commercialism, and the business man with a bigoted and ignorant prejudice against the vitalising effects of Science—should be eradicated from our midst. Science and Industry must co-operate for our national good. There are faint signs of a *rapprochement* to-day, but it must be galvanised into a certainty. The co-operation must be wholehearted; nice mutual-admiration after-dinner speeches in evening dress can be dispensed with. We must have the ' shirt-sleeve ' attitude of the Briton *bent on improvement and development.* Then we shall find that Applied Science, directed into proper channels and unhampered by prejudice, is the nation's strongest weapon to resist the keen competition of our foreign rivals.

Let us see in broad outline to what uses the Scientist could be put, and when we have realised this aspect of the question, we must study the type of man needed, and how best to train him.

IV.

In the previous chapters an endeavour has been made to show that in this country more Chemists should be employed in Industry. To many people it may appear that the only industries in which the Chemist would find scope for his knowledge are those engaged upon what may be termed true chemical operations, such as sulphuric acid manufacture, soap-making, explosives, the production of dyewares, &c. True, it is in such industries as these that one would expect to find the Chemist, but my contention is that every factory, mill, or foundry engaged on the actual manufacture of articles, and hence using a hundred and one different accessory substances, should, simply for its own protection, have its chemical laboratory. To attempt to give proof of this contention in the case of every type of manufacture would be impossible, but I trust the few examples given below will cause the reader to reflect on his own business, and perhaps find there is need for the Scientists therein.

The chemical department of a factory must act in an advisory capacity to the business side. In addition it must control, direct, and develop works operations. The head of the factory must be a technologist, a man possessed of full scientific knowledge of all allied subjects, and also of factory experience. The regulations governing the Austrian factories stipulate that the heads of such concerns must be

trained, fully qualified technologists, just as in the case of our coal-mines the managers must have certain qualifications laid down by Act of Parliament. With these instances in mind, comment on the technologist being head of our factories is unnecessary. My business readers must not think I want the laboratory to be a dictatorial department; rather I look upon it as a department just as essential to a works as its sales department, one dealing solely with its own duties yet working in sympathy with the whole concern. What the actual duties of this department will be will depend naturally upon the industry involved, but broadly speaking they may be classed as under :—

(*a*) To control works processes by periodical tests.

(*b*) To report upon the suitability of material for the works' purposes to the buyers, &c.

(*c*) To standardise all products of manufacture.

(*d*) To initiate improvements and increase the efficiency of the industry.

(*e*) To be alert to match any article, &c.

To carry out the duties enumerated above, the department would have to deal with two classes of work, namely, routine work and research work. In England many people employ Chemists for routine work, but hardly anyone employs the Research Chemist, and this is the real reason we are being outstripped by our foreign competitors. At present

our manufactures are carried out by processes often as old as the industry itself. Empiricism appears rampant, for no one has troubled to probe to the very foundations of such industrial processes. The Research Scientist's duty would be to investigate the whole process as it stood, work out the inter-relationship of each phase, and the effect of changing the order of procedure; in a word, he must expose the skeleton structure upon which the whole is built. He must study his raw materials, know every property of those materials, and above all he must determine the mobility of the processes, and how to vary the products. Once let the true research man gain an insight into the inner meaning of a process and we can anticipate improvement. The aim of the research man must be to see that his firm produces the best goods possible. He must always be on the lookout for methods of cheapening his process, and gaining the maximum yield of finished products. To many business men the employment of such a man may appear a luxury; almost a gamble! The few that have such men are only employing them for some specific object, and, maybe, will rest content when that object has been attained. Such an attitude is fatal. The Chemist feels unsettled, while if the problem is difficult of solution, his employers, not realising the situation, may decide either that he is no use to them, or that Science has failed them, with the result that the man is discharged. A new

man may be engaged who will have to cover the ground again; time is thus lost, dissatisfaction results, and perhaps the manufacturer abandons his hope of obtaining scientific aid in disgust. I cite such an instance because I have actually seen several cases of this nature: cases in which, had the man been given more time, he would have succeeded in solving the problem. Unfortunately instances such as these are due in a large measure to the lack of appreciation by business men of the aims and endeavours of Science, and their lack of knowledge blinds them to the value of the work already done by the Chemist. Time is essential in preparing the scientific foundations upon which improvements and inventions will subsequently be built. Science never reaches finality, for to its adherents one discovery leads to another. True industrial research should be instigated in the same spirit, and research men should be treated as confidential servants of the company, secure in their situation, but realising that they are there to advance their employer's interests, and give him an adequate return for their salary.

Until more is done to clear away the barrier that prevents the commercial man comprehending the vast resources of Science, one cannot hope for an extensive employment of the research man. On the other hand, once let Industry realise the *modus operandi* of Science, and instigate research work, and we shall begin to advance upon sound lines.

The other type of Chemist that the works department would need is the routine man. Now, whilst grouping Chemists into two classes, I do not want it to be supposed that they and their training are distinct, and that one cannot merge into the other; rather is it the difference in their duties that needs description. In many works one man, provided that he displays the true scientific spirit, could play the double rôle, assuming the routine operations do not occupy his whole time and energy, although, for many reasons, it will always pay best to have a man devoting time solely to research, and to employ others upon the daily routine work. Only in cases where, for the time being, there are no apparent problems to be solved would I depend for investigations on the hybrid, but as soon as the need for exhaustive investigation arose, it would pay to turn him on to the research and to engage a man for routine. This brings us to an important point, and that is that not every Chemist is suited by temperament for research work as compared with routine. On the other hand, a man might be an excellent investigator, but a poor routine Chemist.

The duties of the routine Chemist should be devoted to checking all materials supplied to the factory, and he should control the manufacturing processes by periodical tests. He should check every batch of finished articles, and keep them at one uniform standard, namely, the best possible. Natur-

ally his work would bring him in daily contact with all works operations, and any anomalies or surprising results should be carefully noted, and either looked into by himself or brought to the notice of the research department. He should become acquainted with all the other makes of goods on the market, and by analytical work be able, at least approximately, to tell what materials every rival firm is using. Whether or not his own firm could produce such goods at once would depend on several factors. If anything very new were met with that could not be made by their process, it would become the Research Chemist's duty to endeavour to devise means of producing the article. These few remarks may perhaps serve to show that the chemical staff should be concrete, the routine man helping the research man, and the research man devoting himself to any promising suggestions from the routine man. There should be neither discontinuity nor rivalry, either in the department or between the department and the rest of the firm's staff. How necessary such a system is can only be gauged by experience, for often the routine man comes across a need for investigation that has to be shelved through lack of time, but which, if it had been investigated by the whole-time efforts of the research man, would have led to money-saving improvements.

The above remarks with regard to the Research Chemist apply more particularly to chemical indus-

tries and to the industries directly depending upon chemical reactions, and naturally many firms would require a physicist, an engineer, a geologist, or a bacteriologist to conduct their research work. On the other hand, every firm should have their routine Chemist. Consider any firm, taken at random from the many different industries carried out in this country, and you will find they one and all consume a host of chemical substances, either in the form of raw materials or as accessory substances such as coal, lubricating oils, water, &c. The quality of these commodities varies greatly, and cannot be determined by mere inspection. The Chemist can by analytical tests easily sort out the good from the bad. Thus by determining the calorific value, ash, volatile matter, &c., of a coal, he can advise as to the selection of a specific coal likely to give the best return on the price paid for it. Lubricating oils are so easily doctored that a low-grade oil may appear a high-class article, whereas a few viscosity tests and tests of volatility, gumming, and so forth would discover this deception and save much wear and tear of plant. Boiler-feed water requires careful attention. Perhaps choice may be had of several sources, when only analysis can show which is the best. Then, again, in many localities there are solids dissolved in the water that lead to formation of scale in the boiler, and hence the consumption of more fuel to keep steam up.

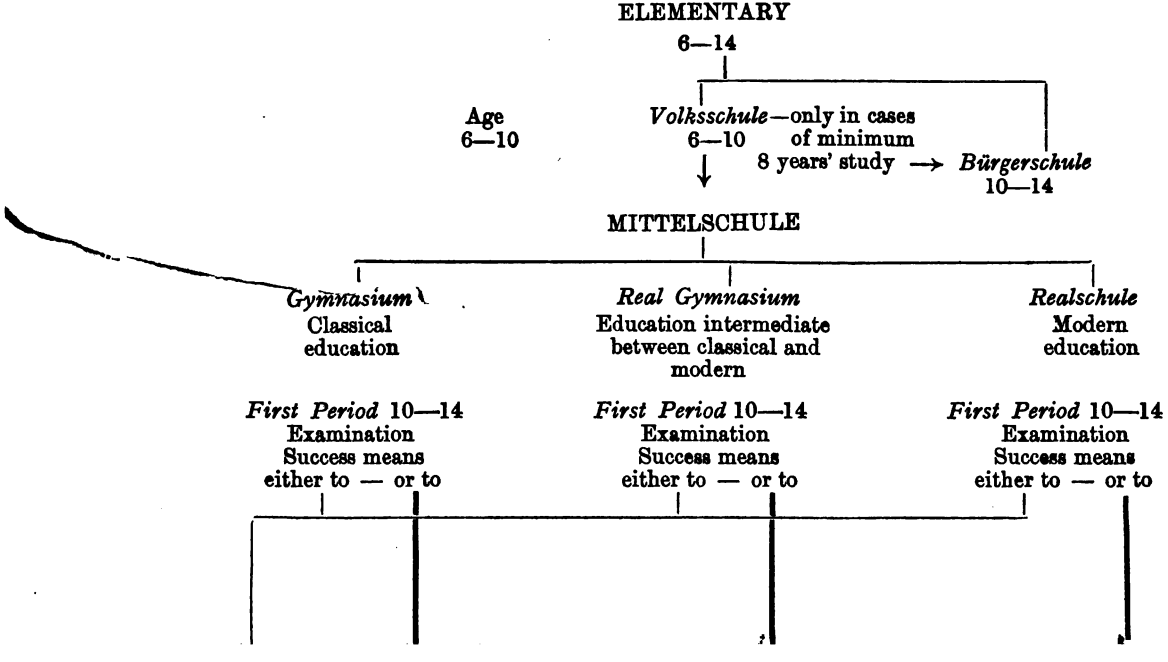
The routine man would see that the water was 'softened' by proper means and prevent this scaling, with all its attendant drawbacks of drawing off the boiler for cleaning and 'chipping.' Not only in these ways can a Chemist save his firm money by fuel economy, he can make frequent tests of the flue gases—that is, check the actual combustion of the fuel. What manufacturer has not at one time or another had a polite note informing him that at such and such a time his chimney was emitting black smoke? That smoke, whilst being obnoxious to the neighbourhood, is also detrimental to himself, for it represents so much unburnt fuel. The cause of this is either improper banking of the fires, unsuitable fuel for the type of boiler, or badly regulated air supply. The Chemist by analysis of the flue gases can determine whether or not the correct amount of air is being admitted, and his selection of fuel would naturally embody consideration of its suitability for the type of boiler-setting in use.

Every firm should see that their raw material is checked at delivery. Tanners, paint makers and users, textile manufacturers, wool scourers, users of building materials, large emporiums and wholesale houses dealing in every type of commodity, even the small foundry and the large retail stores who do not check supplies, are at the tender mercies of the unscrupulous trader. It may be urged by many people that they cannot see their way to employing a

Chemist. There are perhaps a few firms whom it would not pay to do so, but they should invoke the aid of the consulting Chemist, not spasmodically, but as a matter of routine. In many factories little attention is paid to anything outside the actual production of a given article, and the managerial staff have only a limited knowledge of questions relating to fuel, lubrication, engineering, &c. In the nature of things this must often be the case, for the manufacturer is a business expert, not a Scientist. Yet he stands to lose money through lack of appreciation of the importance of subsidiary details. Let him continue to exercise the functions in his concern relating to actual business, but it will pay to have his factory under scientific control.

How much money is made by selling an every-day article in the guise of a speciality with a nice name and done up in fancy wrappings cannot be stated in figures. Yet in every trade such articles are frequently encountered. Thus at a certain brewery the cleaning of the vats was effected regularly by means of a patent composition possessing a nice pink colour and a pleasant odour. The article performed its work quite well, so the firm were quite satisfied to pay half-a-crown a gallon for it, and never bothered any more about it. One day, however, they enlisted the services of a Chemist, and naturally he began to analyse and investigate all materials in use. Our friend the vat cleaner came under his notice.

DIAGRAM OF AUSTRIAN SYSTEM OF EDUCATION.



question, ' Do I know what that is? Is it what I pay for? ' They will find they cannot in many cases supply an answer; then let such people, out of curiosity, invoke scientific aid, and judge by results. I only wish it were possible to get scientific experts in the various trades to converse with the manufacturers, and perhaps then the latter would see a new aspect of affairs. Assuming that our manufacturers wish to enlist to a greater degree the Scientist's services, I am afraid that as things are it would not be possible to supply a very big demand for technical men. True, we have the men, but much remains to be done before they become truly efficient. Let us see what sort of a man we want and what training he must undergo.

V.

The problem of the training of men for a commercial career is naturally closely bound up with our educational policy. There is no doubt our present system needs amendment, with particular stress laid on the co-ordination of the various grades now in existence. Under present conditions each grade is in theory a precursor to the next, whilst in practice there is no great evidence that any particular grade feels it is either a step to the next or a continuation of the one below. What we want is a working system linking up each grade, and the teachers in every grade encouraged, by results, to realise that

He found that it was a solution of caustic soda, dyed to colour and perfumed to taste, the value of the solution being about 1½d. per gallon!

Yet another example similar to the above is the case of a large firm that for twenty-five years had been paying sixpence a pound for a boiler-scale remover. The advent of a Chemist soon stopped this pleasant philanthropy on the part of his firm, for he saw no need to pay three times its value for pharmaceutical hydrochloric acid when the desired result could be attained at a cost of a pound or so a year by other methods. These examples are typical of hundreds of others. It is almost an everyday occurrence to find articles on the market that, whilst admirable for their specified purposes, are sold at prices out of all proportion to their cost of production. In saying this it must be understood that these articles do not embody the results of much endeavour to arrive at their composition; they simply show that someone has realised that a substance in common application can be utilised under fancy names to supply an alleged 'long-felt want.' The presence of a Chemist would soon put an end to this state of affairs, and save firms much money.

Space forbids my dwelling on the hundreds of ways in which a Chemist can save and make money (for his firm). Those of my readers who do not submit anything to analysis have only to go through their own factory and keep asking themselves the

question, ' Do I know what that is? Is it what I pay for? ' They will find they cannot in many cases supply an answer; then let such people, out of curiosity, invoke scientific aid, and judge by results. I only wish it were possible to get scientific experts in the various trades to converse with the manufacturers, and perhaps then the latter would see a new aspect of affairs. Assuming that our manufacturers wish to enlist to a greater degree the Scientist's services, I am afraid that as things are it would not be possible to supply a very big demand for technical men. True, we have the men, but much remains to be done before they become truly efficient. Let us see what sort of a man we want and what training he must undergo.

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they are all part of a huge process of developing the nation's brains to their highest degree.

The system of education in Austria is a grand example of the type we should aim at, and I feel sure the following brief account of its general outline will bring home to my readers the great need for altering the present system of education in England.

The aim of the Austrian people is to train their youths to their highest capacity, for they realise how essential it is for national progress to develop and cultivate powers of independent thought. In Austria every child, irrespective of birth, is compelled to go through a minimum course of education, and whether or not they proceed further with their studies depends on their own capabilities and the attitude of their parents. The minimum course prescribed covers eight years (from the age of six to that of fourteen). The first four years of this course is common to the whole system of education, and is carried on in the ' Volksschule.' When the pupil has completed this initial course of study, the parents are called upon to decide if they wish their child to proceed further than the minimum eight years' course. If they decide upon the latter, the pupil proceeds to the ' Bürgerschule,' and completes the minimum training by attending at this type of school for the remaining four years. Should, however, the parents decide to let their child aim at a higher education, then the pupil on leaving the ' Volksschule ' proceeds to one

or other of the three types of school embraced by the name ' Mittelschule,' or schools for what we call Secondary Education. The three types of school in this division are the ' Gymnasia,' ' Real Gymnasia,' and the ' Realschule,' each designed to meet specific requirements, but of course catering, in the early years of study, for the general school subjects. The ' Gymnasia ' are designed to develop classical education, and hence they specialise in Latin, Greek, &c., and pure mathematics, but not in Science. The opposite type of training to this, *i.e.*, a ' modern ' education, is catered for by the ' Realschule,' in which the special subjects are modern languages, mathematics, and Science, but no Latin or Greek. The third type of school, the ' Real Gymnasium,' is a later addition to the system, designed to meet the demand for an education intermediate in nature between the extreme types. This school is characterised by the teaching of Latin (but not Greek), and of Science and modern languages. The course of study in the ' Gymnasia ' covers a period of eight years (ten to eighteen), whilst attendance in the other two types of school extends over seven years. Each type of school has a break, or rather a halting-place, at the end of the first four years. Thus the pupil when fourteen years old can, if the parents wish it, branch off and pursue a course of commercial training in the ' Handelsschule,' which is designed to fit him for an ordinary business career. Is not

this organised training for business somewhat of a novelty to our ideas, and far preferable to our methods of letting the youth ' pick something up ' as he goes on? One often hears that the representatives of Continental houses are more wide-awake than those of English ones. Can one wonder at it? The Austrians, for example (under these conditions), will have far less difficulty in finding a man equipped with that knowledge of the language and the customs of a country that counts for so much in business. Another reason for this greater knowledge of the Continental representative is to be found in the fact that so many of their youths are sent to England, France, or Germany, as the case may be, for at least a year, and thus study foreign methods. Now to return to the Austrian ' Mittelschule,' the student who does not branch off at fourteen continues his studies along more specialised lines until on reaching the age of seventeen or eighteen, according to the type of school he is in, he has completed his general education. There is then before him the State examination called the ' Maturitäts Prüfûng,' success at which stamps him as worthy of still higher training, and permits of his passing on to the ' Hochschule '—that is, the highest division of education in Austria and on the Continent. Moreover, should his parents' means be small, he is granted a scholarship to maintain him during his studies. In this phase of the question it must be borne in mind that

the Austrian education is under direct State control, and the equivalent of our educational rate is with them more in the nature of a national tax—a tax just as necessary for the prosperity and protection of any country as those devoted to naval and military objects. The Austrian ' Hochschule,' or highest division of education, embraces two types of institution, namely, the University and the ' Technische Hochschule.' The University is divided into four faculties: (*a*) Theology, (*b*) Law, (*c*) Medicine, (*d*) Philosophy. The last-mentioned faculty embraces any branch of Pure Science, for the function of the University is to teach pure subjects or arts, in contrast to technical or Applied Science. These technical subjects are dealt with in the ' Technischen Hochschulen,' which also comprise four faculties, namely, (*a*) Civil Engineering, (*b*) Mechanical and Electrical Engineering, (*c*) Chemistry, (*d*) Architecture.

The student possessed of the ' Maturitäts Prüfûng ' can in general enter either of these types of institution, and in addition any particular one he chooses, but there are certain reservations. It was pointed out that the ' Gymnasia ' give a classical education, and hence their students are designed to enter the University, but should they wish to change over to the technical side they can do so by passing examinations in certain additional subjects. The same is true of ' Realschule ' students, who can at

once proceed to the ' Technische Hochschule ' on obtaining the ' Maturitäts Prüfûng,' but must pass in Latin if they wish to change over to the University. In the case of students qualified in the ' Real Gymnasia,' which, as pointed out above, give an education of a nature between classical and modern, they can proceed without any additional subjects to either type of ' Hochschule.' The courses in the ' Hochschule ' cover four or five years, during which period the student devotes himself to one particular faculty, and at the age of twenty-one or twenty-two emerges fully qualified in either Pure Science, arts, or technical subjects. One point characteristic of this division of the ' Hochschule ' is that all the teachers for the schools are drawn from the University or ' Technische Hochschule,' whilst the army of technologists expanding and controlling the Austrian industries is recruited from the ' Technischen Hochschulen.' This brief and bald account of the Austrian system, which is represented on pp. 114 and 115 in diagrammatic form, cannot but show the definite aim of the scheme, namely, to train for efficiency either in Pure or Applied Science, &c., and, moreover, to keep this aim in view throughout the whole period of study. Let us look at our own system in England, and briefly survey it while bearing this Austrian system in mind.

The scheme now in existence in England may for our purpose be surveyed under three headings :

introductory education, general education, specialised or higher education. The introductory education is carried on by the elementary schools *or* secondary schools *or* public schools. In this, the very commencement of our system, we have a case of overlapping and duplication of functions. There should be one grade, the elementary one, whose function is to ground the pupil in the three R's, and develop the natural curiosity of the child in such a manner as to enable it to *think for itself*. This grade should act as a trial ground in which the individuality of the pupil has a chance of being discovered, and then developed in succeeding grades. There should be no attempt to instil huge masses of indigestible facts into the minds of the pupil; the amassing of facts must come later. Nature study and simple experimental work must be the keynote, combined with smaller classes. Then, having prepared the youthful mind in this way, and given it suppleness and individual power of thinking for itself, we can look forward to a more thinking nation. As soon as the child has, so to speak, gained full benefit from this mental exercise, it is fit to proceed to the secondary school, there to enter on the more serious amassing of knowledge. It is here its general education, *i.e.*, the accumulation of facts, will commence, and with it the serious study of languages, literature, history, geography, mathematics, and elementary Science. This stage must

not be regarded as a "cramming stage," to be judged by examination results, but must once again be an evolutionary process, imparting facts, developing individuality, powers of observation, and above all powers of deduction. Once more, it should be a trial ground for sorting out the pupils whom it will repay the nation to encourage financially and otherwise in continuing their studies in the next higher grade. Our endeavour should be to develop to their fullest extent the intellectual possibilities of our youths, giving everyone a sound general education, training their powers of thinking, and only letting those continue who show natural ability. Having brought the pupil to the standard attainable in general education, he or she should now, if fitted for it, proceed to a higher institution and there begin to specialise.

The institutions we have for imparting instruction in the higher branches of learning vary greatly in their nature and scope. It is at this point that our present system becomes so involved and unwieldy, and overlapping becomes so rife. There are the Technical Schools and Colleges, University Colleges, and Universities of all degrees. There is no standardisation in their functions or results. Some people regard a Technical School as a substitute for the University, others regard it as a step on the way to the higher institution. Others again take no account of the Technical School. The net

result is that both institutions perform much the same work, especially in the early part of their courses, and we have students needlessly repeating their work in their first year or so at the University.

The Technical School should be a precursor to the University, yet another trial ground; in fact, the final trial ground before we permit the student to be regarded as one fitted to be trained as an expert. These lines are not penned in belittlement of the Technical School, as the subsequent remarks will show. To-day we need these institutions for three main reasons, which show how much we need reform. The chief of these is that we need evening instruction in technical work, and the people who attend the classes are people engaged in industry, &c., during the day. The fact of such attendance shows that they have not been fully equipped for their posts, they have not been able, under our present economic and educational systems, to train to the full. Their attendance at classes after a hard day's work shows their willingness to study, but our manufacturers will not make it worth while for them to go the whole hog and become experts. This reveals the weakness of our present system; the Technical School is to many a half-way house, there is no easy path from it to the University, that is, to out-and-out specialisation. Under the new order these institutions must have properly co-ordinated functions, and every institution must have a door

leading to the University, open to all who have shown themselves fitted for downright specialisation. This brings us to the final stage in our educational scheme, the University.

The University should be a State University, the keystone to a great national organisation developed along lines indicated above. This State University of necessity cannot be situated in one place, for it will incorporate all the existing Universities, such as those of Birmingham, Leeds, Liverpool, &c. The underlying principle will be to centralise the teaching of the pure science in divisional colleges, and localise the teaching of the applied subjects in the heart of the district wherein a particular industry is carried on. Thus we should have the teaching of the technology of textile manufactures situated at Leeds, Bradford, and Manchester. Birmingham, Sheffield, &c., would become seats of instruction in the metallurgy of steel and iron, and so on for every industry.*

It should not be assumed from this that we should only find the manufacture of textiles taught, say, at Bradford, and that the chemistry, physics, engineering, and other departments should be converted to other uses. Far from it; the textile trade needs its chemists and its engineers, and under a properly regulated scheme the teaching in these subjects would bear directly on the trade concerned. The

* Since these lines were written Sheffield University has become a constituent College of the Imperial College of Science and Technology.

students at these classes would be men who had already climbed the educational ladder, and are now specialising, after receiving instruction in Pure Science at the Central University. There is a lot to be said for this scheme from an educational standpoint, while as a business scheme it will stand the closest scrutiny. Under its régime we should save thousands of pounds by prevention of the overlapping of expenditure on institutions. This saving would permit of getting real technologists on the staffs of the institutions, and the Pure Science teaching could be more thorough, whilst the technological training would likewise be more real.

There are people who may feel that there is no need to train men to such a pitch as outlined above, and that employers can get all they want by ' bringing up ' people on the works. ' Fatal ' is not the word to describe such a policy. Men are needed of the *highest* ability, training, and skill we can produce, devoting their energy to the expansion and maintenance of our commercial operations; men to investigate, to probe and prune our industries. The works-trained man can seldom develop into such a person, for the technologist requires all the knowledge he can get. Moreover, he wants the breadth of outlook, the ' spirit of his science,' and the power of original thinking that can only be attained in perfection by working and studying in the stimulating atmosphere of an academic institution.

Remember that it is the academic man who is probing into Nature and causing her to reveal her secrets. We want the refined and searching methods of the academic man at the call of industry, to elucidate the hundred and one problems of everyday occurrence. Compared with the delicate methods of the man of academic attainment, works processes are crude and cumbersome. The youthful mind is readily influenced, and consequently the average works ' trained ' man comes to have a crude and rugged idea of his subject—in fact, only such knowledge as is contained within the four walls of one factory. As a man capable of thoroughly threshing out a problem he is useless compared with the individual possessed of University training. The man on a mountain-top can see far more than a man on a boulder at the foot thereof, provided it is not misty at the top. Our trained man is in the position of the man on the mountain; in front of him spreads the broad view of his subject, but we must see to it that his industrial view is not hampered by being solely academic. We want the widest academic view possible, but we want powers of applying it to industrial problems. The commercial man is prone to describe the academic man as unpractical. The latter may retort with equal force that the commercial man is not theoretical. People will argue about the relative importance of theory and practice, and dogmatically assert that one is of more importance than the other.

They might as well argue which is the more important, the right or left side of the body. Together they constitute a homogeneous entity. Practice and theory are interwoven. In England from a commercial standpoint they are more or less asunder. We must link them firmly up in order to maintain and above all expand our industrial position. The link is the expert. In the future we must divert many of our University men into industrial channels, and spare no effort to train them to the highest pitch as technologists in its widest meaning. There is much to be done before this can be accomplished. Let us consider some of the main reasons for the present dearth of such men, and make some suggestions as to the lines upon which we can alter existing conditions in order to attain greater efficiency in the future.

VI.

The results accruing from the money and energy that we spend upon education are meagre in comparison with the return that might be got from a scheme which would make proper use of the trained man. The number of trained men who enter a commercial walk in life is insignificant compared with the number that enter the teaching profession. The youth who leaves school and proceeds to the University, and spends there three or four years in studying chemistry, finds in general that there are

few posts open to him. Moreover, he will find that works posts are conspicuous by their rarity. The result is that he will become, willy-nilly, a teacher. In this capacity he retails the more elementary portion of his knowledge to the rising generation. Some of his pupils become interested in his science and decide to devote themselves to it. In course of time they, too, go to the University, spend three or four years studying, and—once again, in the majority of cases—they, too, become teachers. What a wasteful cycle, one generation becoming teachers of the next, without rhyme, reason, or regard as to their suitability. In similar cases on the Continent we should find that a large number of these men would have been absorbed into commercial undertakings, there to devote their knowledge and energy to expand and perfect manufacturing processes and business enterprises. We Englishmen should see to it that such a condition of things may be brought about in this country. It would revolutionise our industries; it would make education a real live force. How many students fight shy of specialising because they feel there is no call for such knowledge? The result of the institution of a system that allowed of the trained man entering into commercial work and having his worth recognised would be that many more would train, our average standard of knowledge would commence to reach a higher level, concurrent with this change our industries and the standard of

their products, methods, &c., would improve. Education would become more real, more alive, because this commercial outlet would give it a very definite aim.

Our teachers would be able to become such from choice, not from necessity, and this enthusiasm and aptitude of the natural teacher would still further help forward this march of intelligence, training, and specialisation. Yet again, educational expenditure could be regarded from a business standpoint, giving its return in the added profits of industry due to the application of the Scientist to commercial walks in life. The teaching profession could be made more attractive by higher emoluments due to keener appreciation of its merits, and real technologists could be appointed on the staffs of colleges—men there from choice, after having spent some years in commercial work. These men would mould the technologist from the pupil possessed of a full knowledge of Pure Science. This question of a proper utilisation of the trained Scientist is at the root of the whole matter; unless we solve it education will continue stunted, a few men will become technologists, but the wasteful cycle mentioned above will still go on. How are we to bring the new state of affairs about? In one way only.

Industry and Science must co-operate for the nation's good. It is up to the manufacturers to make the move. I say with all respect that the majority

of manufacturers have no appreciation of the ways and methods of Science. There are many manufacturers in this country who have never tapped the vast stores of knowledge bearing directly on their particular industry. How many firms use the same process that was in vogue when they first devoted themselves to a certain industry, and how many of these people would find on reading their subject up that there had been a vast number of improvements since then. The commercial man cannot find time to devote to this side of the question, but if he employed a genuine Scientist his industry would through him be able to keep up to date. Many of our commercial men are awakening to the influence Applied Science is having on industry, but their full appreciation of the fact and their whole-hearted support are needed before we can really run our manufactures on truly scientific lines. Firms in this country that make use of the Scientist on thorough lines are now reaping the reward. Yet it seems a general feeling among business people that to employ a Scientist is a sort of luxury. If a real genuine Scientist possessed of the qualities demanded for industrial work can be obtained, he would no longer be regarded as a luxury, but as a necessity. The argument may be urged that it is impossible to obtain such a man. Up to a certain point that is true; it is not always possible to find men who have made a special study of any one particular industry, and

that is why I say it is for the manufacturers themselves to make the first move. They know very well that if there is a demand for a certain article a supply will be thereby created to meet the demand; also, they know that the reverse is true and that supply is useless without a demand. Under present conditions there is no genuine demand for the technologist. The previous chapter will give in broad outline some idea of the training needed in order to fit a person to become capable of originating and developing an industry to its full extent. Yet if a young man were to follow this out to its utmost he would find that in general when he had finished his training he would be—stranded!

It must be remembered that he must first attain his training in Pure Science and then strike out on his training in technology. This means he must become possessed of a general knowledge of chemical engineering, chemical plant, means of handling goods, and methods of grafting his Pure Science on to industrial problems. He must study and specialise. This specialisation can take place in so many ways, and what incentive is there for him to pursue such a course in technology when the chances are a hundred to one against him having the opportunity to utilise his knowledge in a commercial way? The consequence is that the majority of our Chemists stop short in their training at a certain stage, devote themselves to the Pure Science, and subsequently

become teachers. This is the reason we have not an army of technologists. Industry offers too scanty a field for a Chemist. Speaking from a commercial standpoint, we do not realise the far-reaching effect that the multitudinous ramifications of Science are capable of producing in our industrial undertakings. Many people are content if they have a few tests carried out on rigid routine lines. In general these tests are done by a person who has grown up from boyhood in the works, and subsequently become familiar with the daily tests. Such work, we know, must be done, it is essential to economic working, and for much of it as carried on to-day the routine man suffices. But, and this is the point, there is a need, a crying need, for higher work. Our manufacturers fail to realise how much more efficiently this work could be carried out by men possessed of greater elasticity of mind and a broader outlook. They will not give credence to the fact that what to them may appear an unfortunate happening in the works operations, resulting in a spoiled batch, may be capable in the hands of the Scientist of easy solution, and result in a subsequent improvement in the process. We need the man *able to initiate*, *able to investigate*, able to develop, to be on guard in our works, ready at any moment to fasten on to anything not properly understood, and wrest from it its inner meaning. If only some people in charge of works had a slight inkling of the scientific meaning

and knowledge attached to what to them may seem everyday processes governed by chance, they would be appalled. But they have not, and they will not hearken to the Scientist because he is, they say, 'not practical.' He has not had charge of their particular plant. Let them take a Scientist into their works; in six weeks he will be practical, for his training so moulds his outlook that he can readily imbibe the details of works processes. Science is not simply a collection of facts and formulæ, but a delicate network of principles, laws, and relationships. Many of our chemical industries had their birth in the laboratory, and have grown to what they are by the fostering care of the man possessed of theoretical knowledge combined with commercial aptitude. This is the point at which Science merges into Industry. It is the stage at which we need the influence of co-operation to allow of the passage of our scientifically trained youth into the technical expert. It can only be brought about by smoothing down the rugged ground of prejudice existing between college and works, and giving the student a chance to gain real first-hand commercial experience of costs and markets. There is no need for a revolutionary upheaval, for we can evolve a system from the existing conditions that will allow of our trained youth gradually entering commerce as a real genuine technologist. Let us consider some suggestions for hastening on a movement fraught with such national importance.

VII.

One cannot, and does not, expect the commercial man suddenly to blossom out into a Scientist, for his activities as a business man are essential to industrial prosperity; but as a business man one does expect him to consider without prejudice any proposition bearing upon his commercial activities. This question of Science and Industry is a genuine business proposition which under proper conditions is capable of yielding a handsome return, but these proper conditions can only be attained by commercial men realising what Science has done, is doing, and can do in the future.

There is a certain type of commercial man who considers the Scientist unpractical, and hence of no value in industry. Now it is true the man who has just finished his training has not actual works experience, but he possesses knowledge that centuries of works experience will never give him, and he only needs actual contact with the works processes and appliances to be able to interpret his knowledge on a commercial basis. Thus in the refining, say, of coal-tar products, the principles he has imbibed from the study of liquid mixtures go to the very root of the industry on the large scale. There is this difference: in his training course he has used apparatus constructed of glass, fractionating columns of size to give him the best result possible in his work; he has been able to use as many receiving vessels as

he likes, and perhaps made a greater number of intermediate products than would be possible in the works process. But what does it matter? The principles underlying fractionation are the same in the works and in the laboratory; the student only needs an opportunity to witness works processes, and by virtue of his training and of the elasticity of mind it gives him he can readily attain to an understanding of the works process. One phase of the question in which the manufacturer can do so much to help in the training of the technologist is by simply allowing the local institutions to visit his works and witness actual works operations. There are many public-spirited people who do this to-day, and one generally finds such people are reaping the benefit of having a Scientist in their employment. Others may object that such visits would lead to the disclosure of works secrets. I think not, for I have been on many such visits, and have noticed there is no divulging of secrets. Now it must be borne in mind that the students do not come on such visits to learn the process—they know it already and all its underlying principles—they come there to see large-scale operations, and become familiar with the factory equivalent of the apparatus known to them in the college. These factory appliances have been evolved from the academic apparatus, and we want our students to attain to the same sequence of ideas that lead up to this evolution of works plant.

Another way in which factory and college can become more closely knit is by the college reciprocating for these works visits in assisting the manufacturer in the choice of his Chemists, and, if needs be, placing their academic laboratories at his disposal.

As everyone acquainted with scientific investigation is aware, occasions arise that call for elaborate apparatus and academic facilities not ordinarily to be found in works laboratories. The installation of such equipment would mean a heavy outlay for apparatus that might be rarely used. It is upon these and similar occasions that the college should assist the manufacturer and place their fully equipped laboratories at his disposal.

The University of Kansas has in operation a scheme of Bursaries in applied chemistry. These Bursaries, which are endowed by local manufacturers, are awarded to students who have graduated in pure chemistry, and are well grounded in the applied science. The student to whom one of these Bursaries has been awarded remains at the University, but is engaged upon the solution of some works problem for the manufacturer who is, so to speak, subsidising him. The results of the investigation in question belong to the manufacturer, and in return for the solution of the problem the graduate is given a certain bonus and the opportunity to take up a post with the firm he has been working for. The work is carried out in the college, and the manufacturer

is spared the expense connected with the installation of a laboratory equipped for research. His interests are protected by the Professor, who renders periodical reports upon the work. Such a scheme as this may appeal to many as being all that is needed to bind together our colleges and the factory, but I feel there are too many pitfalls for it to be of real lasting utility. In the first place, it may lead many factories, should they adopt it, not to engage the Chemist, but to send all cases of investigation to the college, and continue running their operations on the same old-fashioned lines, with the result that many happenings will escape investigation, and the day when the technologist will be in most of our factories controlling and developing the processes will be no nearer. A modified form of these Bursaries as mentioned above would lead to lasting results *only* when the factory actually has its chemical staff in the works, and is utilising the college's facilities as an extra aid. It is essential that the factory should have its chemical staff on the spot, ever on the alert to fasten on to every occurrence the reason of which is not clear. With a fuller appreciation of Science and experience of its working, our manufacturers as business men will realise the great value of the trained Scientist in developing, controlling, and operating commercial processes. They will realise that whilst they need the expert technologist to develop and expand, they also need

the trained man to control the works. It would be to their benefit if every one of their workmen were possessed of a certain amount of training other than that gained in the works. The man to control the operations will evolve from the conditions under which we train the expert, for it should be remembered that in the scheme of education outlined in Chapter V we cannot ticket a certain student for research or routine work and force him into it. Let us return to the question of the foremen, &c., possessed of training and understanding, and from this point of view consider how we can build up a more efficient army of controllers of operations. The foundation from which we start is the evening student.

The majority of students attending evening classes in the technical schools are youths who are engaged during the day in industrial occupations. The very fact that they sacrifice their evenings in order to make themselves more fitted for their commercial work is evidence that they realise the value of Science, but that unfortunately their early training has been cut short. Do our manufacturers make full use of this type of employé, and do they encourage such people to continue their studies by utilising the knowledge they have already attained? In many cases the answer is in the negative, but there are some of these evening students who get a chance to rise because of their knowledge. The

evening men under consideration are those who have spent four or five sessions in the classes, first studying pure chemistry and allied subjects, and subsequently attending classes in the technology of their particular industry. The man who has only attended one session in the technology of his subject is out of consideration here, but unfortunately some people have in the past regarded him as a trained man, and through his shortcomings have decided that Science was of no use to them. The type of evening man the manufacturer must encourage is the four or five session student, who has gained considerable knowledge at much hardship to himself. Once let our manufacturers realise the value such a man has, and they in all fairness will remove this great hardship, for there is a limit to the period over which the brain remains supple, active, and retentive. I know of men who commence their day's work at six in the morning, stop at five at night, and then attend classes from seven till ten in the evening. It is beyond human power to gain the maximum benefit from their studies, it is not fair to let them continue under such conditions. That they are men of ambition and energy is shown by this attendance at evening classes, and hence they should be encouraged by having time allowed off during the day. This would be to the manufacturers' advantage, because they would then be getting a more efficient man in their works. We need a modified

revival of the apprenticeship system, allowing off time for study. A scheme such as is in operation in our dockyards could be brought into vogue. The apprentices in our dockyards are allowed a certain term of attendance at the dockyard school. Every apprentice has this minimum training in his early days, but there is the opportunity for those of ability and perseverance to continue this school attendance in succeeding years. Continuation is only allowed to those who show that they have benefited by the prescribed minimum, and their continuation is determined from year to year by their past record. The attendance at school takes place mainly during dockyard hours. Efficiency is a bar to 'malingering,' for immediately a student loses interest in his studies his schooling ceases, and he spends his time in the shops. The results attained by such a scheme are sufficient guarantee of its value. In the engineering world former dockyards apprentices are to be found in high places, and practically every year the National Scholarships and Whitworth Scholarships and Exhibitions are carried off by these men. Several large firms in this country have such a scheme in practice, but they are very few by comparison. The majority of such firms allow their apprentices certain afternoons off in order to attend classes at technical schools, the continuance of this privilege being determined by the progress of the youth. This type of scheme needs wide extension

and amplification, so that in course of time evening schools may cease to exist as such, for the work will be done in the day. Evening work could then be of the nature of extension lectures delivered to men possessed of a good general knowledge, and hence the lecturer would be able to deal with the higher branches of Pure Science and Technology, and the lectures be of the nature of those courses of University Extension Lectures now delivered in various centres by experts attached to the Universities. There would also result from this apprenticeship scheme a wider and more useful sphere for our day technical schools. If commercial men would only try to test the utility of the trained man by adopting some such scheme in their factories, they would realise the value of this type of man to them in the routine of factory management. When in addition they realise the value of the technologist as adviser and director of operations, we can hope to see in England a system of education similar in general outline to that now in vogue in Austria and elsewhere on the Continent.

VIII.

The foregoing pages contain an honest attempt to view the question of Science and Industry from an impartial standpoint. They were written because I feel that we in this country are falling behind in utilising Applied Chemistry. Other countries are

ahead of us; they have realised the value of the Chemist to Industry. Applied Chemistry in their hands has become, and will become still more so in the future, a mighty weapon of attack upon our markets. Competition in every walk of commerce becomes keener year by year. Efficiency will be the deciding factor in the stability of nations. The future Great Powers will not be those who possess the largest navies and armies, but those who possess the greatest number of trained intellects. The whole conditions of life, individually, nationally, and internationally, are slowly changing. Our present eminence in international affairs has arisen from our great national asset of a home coal supply, combined with our English temperament. No doubt in the past we turned to commerce and became the pioneers therein, because we were the first nation to outgrow the resources of our country and to require food supplies from elsewhere. We had to expand, and our desire for expansion culminated in the British Empire, an Empire mapped out by the pluck and bravery of our soldiers and sailors, consolidated into a whole by our statesmen, but held together and maintained by our energies in commerce. Its integrity depends upon our commercial prosperity. When our industries had their birth Science was yet an infant, Industry could not invoke its aid. To-day Science is healthy, strong, supple, and pliant. Its aid is invoked by other countries bent on expansion; it has

yielded up to them rich secrets and shown directions of expansion. As a nation we must employ it for our own benefit, to strengthen our present industries and build up new ones. Upon our manufacturers depends our prosperity; they it is who determine the manipulations of Industry. Upon them depends whether or not we utilise this mighty weapon of Applied Science to its full extent. We can train Chemists equal to those of any other nation. We are not doing this as we should, for Science and Industry are not working in full sympathy. Our educational institutions are ready to do their part; they want the manufacturer and the employer to join forces with them; they want their help to help the nation. The question should be discussed from both standpoints. Realise what our rivals in trade are doing. Approach this great question in that broadminded manner characteristic of this nation's business reputation. Then, when after mature deliberation and by experience it is found that Science can help in manifold ways, hold out the hand of Industry and grip that of Science. Let the clasp seal the compact to work in sympathy. Tackle the required innovations along business lines. Then we shall have the mighty forces of Industry, Science, and Education moving forward shoulder to shoulder for the mutual benefit, welfare, and prosperity of the nation.

THE INFLUENCE OF BRAIN POWER ON HISTORY AND INDUSTRY.

By Sir Norman Lockyer, K.C.B., LL.D., F.R.S.

Abridged from an Address delivered by him to the British Association at Southport, 1903, *with Notes on the Present Position by* Professor R. A. Gregory.

The century into which we have now well entered may be more momentous than any which has preceded it, and the present history of the world is being so largely moulded by the influence of brain-power, which in these modern days has to do with natural as well as human forces and laws, that statesmen and politicians will have in the future to pay more regard to education and science as empire-builders and empire-guarders than they have paid in the past.

The nineteenth century will ever be known as the one in which the influences of science were first fully realised in civilised communities; the scientific progress was so gigantic that it seems rash to predict

that any of its successors can be more important in the life of any nation.

Disraeli, in 1873, referring to the progress up to that year, spoke as follows: 'How much has happened in these fifty years—a period more remarkable than any, I will venture to say, in the annals of mankind. I am not thinking of the rise and fall of Empires, the change of dynasties, the establishment of Governments. I am thinking of those revolutions of science which have had much more effect than any political causes, which have changed the position and prospects of mankind more than all the conquests and all the codes and all the legislators that ever lived.'*

The progress of science, indeed, brings in many considerations which are momentous in relation to the life of any limited community—any one nation. One of these considerations to which attention is now being greatly drawn is that a relative decline in national wealth derived from industries must follow a relative neglect of scientific education.

It was the late Prince Consort who first emphasised this when he came here fresh from the University of Bonn. Hence the 'Prince Consort's Committee,' which led to the foundation of the College of Chemistry, and afterwards of the Science and Art Department. From that time to this the warnings of our men of science have become louder

* *Nature*, November 27, 1873, vol. ix. p. 71.

and more urgent in each succeeding year. But this is not all; the commercial output of one country in one century as compared with another is not alone in question; the acquirement of the scientific spirit and a knowledge and utilisation of the forces of Nature are very much further reaching in their effects on the progress and decline of nations than is generally imagined.

Britain in the middle of the last century was certainly the country which gained most by the advent of science, for she was then in full possession of those material gifts of Nature, coal and iron, the combined winning and utilisation of which, in the production of machinery and in other ways, soon made her the richest country in the world, the seat and throne of invention and manufacture, as Mr. Carnegie has called her. Being the great producers and exporters of all kinds of manufactured goods, we became eventually, with our iron ships, the great carriers, and hence the supremacy of our mercantile marine and our present command of the sea.

The most fundamental change wrought by the early applications of science was in relation to producing and carrying power. With the winning of mineral wealth and the production of machinery in other countries, and cheap and rapid transit between nations, our superiority as depending upon our first use of vast material resources was reduced. Science, which is above all things cosmopolitan—planetary,

not national—internationalises such resources at once. In every market of the world

> ' things of beauty, things of use,
> Which one fair planet can produce,
> Brought from under every star,'

were soon to be found.

Hence the first great effect of the general progress of science was relatively to diminish the initial supremacy of Britain due to the first use of *material* resources, which indeed was the real source of our national wealth and place among the nations.

The unfortunate thing was that, while the foundations of our superiority depending upon our *material resources* were being thus sapped by a cause *which was beyond our control*, our statesmen and our Universities were blind leaders of the blind, and our other asset, our mental resources, which was within our control, was culpably neglected.

So little did the bulk of our statesmen know of the part science was playing in the modern world and of the real basis of the nation's activities, that they imagined political and fiscal problems to be the only matters of importance. Nor, indeed, are we very much better off to-day. In the important discussions recently raised by Mr. Chamberlain, next to nothing has been said of the effect of the progress of science on prices. The whole course of the modern world is attributed to the presence or absence of taxes on certain commodities in certain

countries. The fact that the great fall in the price of food-stuffs in England did not come till some thirty or forty years after the removal of the corn duty between 1847 and 1849 gives them no pause; for them new inventions, railways, and steamships are negligible quantities; the vast increase in the world's wealth, in Free Trade and Protected countries alike, comes merely, according to them, in response to some *political* shibboleth.

We now know, from what has occurred in other States, that if our Ministers had been more wise and our Universities more numerous and efficient, our *mental resources* would have been developed by improvements in educational method, by the introduction of science into schools, and, more important than all the rest, by the teaching of science by experiment, observation, and research, and not from books. It is because this was not done that we have fallen behind other nations in properly applying science to industry, so that our applications of science to industry are relatively less important than they were. But this is by no means all; we have lacked the strengthening of the national life produced by fostering the scientific spirit among all classes and along all lines of the nation's activity; many of the responsible authorities know little and care less about science; we have not learned that it is the duty of a State to organise its forces as carefully for peace as for war; that Universities and other

teaching centres are as important as battleships or big battalions; are, in fact, essential parts of a modern State's machinery, and, as such, to be equally aided and as efficiently organised to secure its future well-being.

The Struggle for Existence in Modern Communities.

Some years ago, in discussing the relations of scientific instruction to our industries, Huxley pointed out that we were in presence of a new 'struggle for existence,' a struggle which, once commenced, must go on until only the fittest survives.

It is a struggle between organised species—nations—not between individuals or any class of individuals. It is, moreover, a struggle in which science and brains take the place of swords and sinews, on which depended the result of those conflicts which, up to the present, have determined the history and fate of nations. The school, the University, the laboratory, and the workshop are the battlefields of this new warfare.

But it is evident that if this, or anything like it, be true, our industries cannot be involved alone; the scientific spirit, brain-power, must not be limited to the workshop, if other nations utilise it in all branches of their administration and executive.

It is a question of an important change of front. It is a question of finding a new basis of stability

for the Empire in face of new conditions. I am certain that those familiar with the present state of things will acknowledge that the Prince of Wales's call, 'Wake up,' applies quite as much to the members of the Government as it does to the leaders of industry.

What is wanted is a complete organisation of the resources of the nation, so as to enable it best to face all the new problems which the progress of science, combined with the ebb and flow of population and other factors in international competition, are ever bringing before us. Every Minister, every public department, is involved; and this being so, it is the duty of the whole nation—King, Lords, and Commons—to do what is necessary to place our scientific institutions on a proper footing in order to enable us to 'face the music,' whatever the future may bring.

The idea that science is useful only to our industries comes from want of thought. Very few people realise the immense number of scientific problems the solution of which is required for the State service. The nation itself is a gigantic workshop; and the more our rulers and legislators, administrators and executive officers possess the scientific spirit, the more the rule of thumb is replaced in the State service by scientific methods, the more able shall we be, thus armed at all points, to compete successfully with other countries along all lines of national as well as of commercial activity.

It is obvious that the power of a nation for war, in men and arms and ships, is one thing; its power in the peace struggles to which I have referred is another. In the latter the source and standard of national efficiency are entirely changed. To meet war conditions, there must be equality or superiority in battleships and army corps. To meet the new peace conditions, there must be equality or superiority in Universities, scientific organisation, and everything which conduces to greater brain-power.

Our Industries are suffering in the present International Competition.

The present condition of the nation, so far as its industries are concerned, is as well known, not only to the Prime Minister, but to other political leaders in and out of the Cabinet, as it is to you and to me. Let me refer to two speeches delivered by Lord Rosebery and Mr. Chamberlain on two successive days in January, 1901.

Lord Rosebery spoke as follows :—

'. . . The war I regard with apprehension is the war of trade which is unmistakably upon us. . . . When I look round me I cannot blind my eyes to the fact that, so far as we can predict anything of the twentieth century on which we have now entered, it is that it will be one of acutest international conflict in point of trade. We were the first

nation of the modern world to discover that trade was an absolute necessity. For that we were nicknamed a nation of shopkeepers; but now every nation wishes to be a nation of shopkeepers too, and I am bound to say that when we look at the character of some of these nations, and when we look at the intelligence of their preparations, we may well feel that it behoves us not to fear, but to gird up our loins in preparation for what is before us.'

Mr. Chamberlain's views were stated in the following words :—

'I do not think it is necessary for me to say anything as to the urgency and necessity of scientific training. . . . It is not too much to say that the existence of this country, as the great commercial nation, depends upon it. . . . It depends very much upon what we are doing now, at the beginning of the twentieth century, whether at its end we shall continue to maintain our supremacy or even equality with our great commercial and manufacturing rivals.'

Trade no longer follows the flag as in the old days, but follows the brains, and our manufacturers are too apt to be careless in securing them. In one chemical establishment in Germany 400 doctors of science, the best the Universities there can turn out, have been employed at different times in late years. In the United States the most successful students in the higher teaching

centres are snapped up the moment they have finished their course of training, and put into charge of large concerns, so that the idea has got abroad that youth is the password of success in American industry. It has been forgotten that the latest product of the highest scientific education must necessarily be young, and that it is the training and not the age which determines his employment. In Britain, on the other hand, apprentices who can pay high premiums are too often preferred to those who are well educated, and the old rule-of-thumb processes are preferred to new developments—a conservatism too often depending upon the master's own want of knowledge.

[See the Report of the Special Committee on the Practical Training of Engineers, issued by the Institution of Civil Engineers. Dr. W. C. Unwin, F.R.S., the Chairman of the Committee, stated that two out of every three students who had been through his hands at the Central Technical College were unable to pay premiums, and that these included the ablest men. This is the experience also of most teachers of engineering subjects in universities and technical institutions.]

The Necessity for a Body dealing with the Organisation of Science.

The present awakening in relation to the nation's real needs is largely due to the warnings of men of science. But Mr. Balfour's terrible Manchester

picture of our present educational condition* shows that the warning, which has been going on now for more than fifty years, has not been forcible enough; but if my contention that other reorganisations besides that of our education are needed is well founded, and if men of science are to act the part of good citizens in taking their share in endeavouring to bring about a better state of things, the question arises, Has the neglect of their warnings so far been due to the way in which these have been given?

At present, appeals on this or on that behalf are the appeals of individuals; science has no collective voice on the larger national questions; there is no organised body which formulates her demands. During many years it has been part of my duty to consider such matters, and I have been driven to the conclusion that our great crying need is to bring about an organisation of men of science and all interested in science similar to those which prove so effective in other branches of human activity.

We in this Empire certainly need to organise science as much as in Germany they find the need to organise a navy. The German Navy League, which has branches even in our Colonies, already has a membership of 630,000, and its income is nearly

* 'The existing educational system of this country is chaotic, is ineffectual, is utterly behind the age, makes us the laughing-stock of every advanced nation in Europe and America, puts us behind, not only our American cousins, but the German and the Frenchman and the Italian.'—*Times*, October 15, 1902.

£20,000 a year. A British Science League of 500,000 with a sixpenny subscription would give us £12,000 a year, quite enough to begin with.

The First Work of such an Organisation.

I suppose it is my duty, after I have suggested the need of organisation, to tell you my personal opinion as to the matters where we suffer most in consequence of our lack of organisation at the present time.

Our position as a nation, our success as merchants, are in peril chiefly—dealing with preventable causes—because of our lack of completely efficient Universities and our neglect of research. This research has a double end. A professor who is not learning cannot teach properly or arouse enthusiasm in his students; while a student of anything who is unfamiliar with research methods, and without that training which research brings, will not be in the best position to apply his knowledge in after-life. From neglect of research comes imperfect education and a small output of new applications and new knowledge to reinvigorate our industries. From imperfect education comes the unconcern touching scientific matters and the too frequent absence of the scientific spirit in the nation generally, from the Court to the Parish Council.

I propose to deal as briefly as I can with each of these points.

Universities.

I have shown that, so far as our industries are concerned, the cause of our failure has been run to earth; it is fully recognised that it arises from the insufficiency of our Universities both in numbers and efficiency, so that not only our captains of industry, but those employed in the nation's work generally, do not secure a training similar to that afforded by other nations. No additional endowment of primary, secondary, or technical instruction will mend matters. This is not merely the opinion of men of science; our great towns know it, our Ministers know it.

It is sufficient for me to quote Mr. Chamberlain:

'It is not everyone who can, by any possibility, go forward into the higher spheres of education; but it is from those who do that we have to look for the men who in the future will carry high the flag of this country in commercial, scientific, and economic competition with other nations. At the present moment I believe there is nothing more important than to supply the deficiencies which separate us from those with whom we are in the closest competition. In Germany, in America, in our own colony of Canada, and in Australia, the higher education of the people has more support from the Government, is carried further, than it is here in the Old Country; and the result is that in every pro-

fession, in every industry, you find the places taken by men and by women who have had a University education. And I would like to see the time in this country when no man should have a chance for any occupation of the better kind, either in our factories, our workshops, or our counting-houses, who could not show proof that in the course of his University career he had deserved the position that was offered to him. What is it that makes a country? Of course you may say, and you would be quite right, "The general qualities of the people, their resolution, their intelligence, their pertinacity, and many other good qualities." Yes; but that is not all, and it is not the main creative feature of a great nation. The greatness of a nation is made by its greatest men. It is those we want to educate. It is to those who are able to go, it may be, from the very lowest steps in the ladder, to men who are able to devote their time to higher education, that we have to look to continue the position which we now occupy as at all events one of the greatest nations on the face of the earth. And, feeling as I do on these subjects, you will not be surprised if I say that I think the time is coming when Governments will give more attention to this matter, and perhaps find a little more money to forward its interests."*

Our conception of a University has changed. University education is no longer regarded as the

* *Times*, November 6, 1902.

luxury of the rich, which concerns only those who can afford to pay heavily for it. The Prime Minister in a recent speech, while properly pointing out that the collective effect of our public and secondary schools upon British character cannot be overrated, frankly acknowledged that the boys of seventeen or eighteen who have to be educated in them 'do not care a farthing about the world they live in except in so far as it concerns the cricket-field or the football-field or the river.' On this ground they are not to be taught science; and hence, when they proceed to the University, their curriculum is limited to subjects which were better taught before the modern world existed, or even Galileo was born. But the science which these young gentlemen neglect, with the full approval of their teachers, on their way through the school and the University to politics, the Civil Service, or the management of commercial concerns, is now one of the great necessities of a nation; and our Universities must become as much the insurers of the future progress as battleships are the insurers of the present power of States. In other words, University competition between States is now as potent as competition in building battleships; and it is on this ground that our University conditions become of the highest national concern, and therefore have to be referred to here, and all the more because our industries are not alone in question.

Why we have not more Universities.

Time was when the Navy was largely a matter of private and local effort. William the Conqueror gave privileges to the Cinque Ports on the condition that they furnished fifty-two ships when wanted. In the time of Edward III, of 730 sail engaged in the siege of Calais, 705 were 'people's ships.' All this has passed away; for our first line of defence we no longer depend on private and local effort.

Time was when not a penny was spent by the State on elementary education. Again, we no longer depend upon private and local effort. The Navy and primary education are now recognised as properly calling upon the public for the necessary financial support. But when we pass from primary to University education, instead of State endowment we find State neglect; we are in a region where it is nobody's business to see that anything is done.

We in Great Britain have thirteen Universities competing with 134 State and privately endowed in the United States and twenty-two State-endowed in Germany. I leave other countries out of consideration for lack of time, and I omit all reference to higher institutions for technical training, of which Germany alone possesses nine of University rank. The German State gives to one University more than the British Government allows to all the Universities and University Colleges in England, Ireland, Scotland, and Wales put together. These are the

conditions which regulate the production of brain-power in the United States, Germany, and Britain respectively, and the excuse of the Government is that this is a matter for private effort. Do not our Ministers of State know that other civilised countries grant efficient State aid, and, further, that private effort has provided in Great Britain less than 10 per cent. of the sum thus furnished in the United States in addition to State aid? Are they content that we should go under in the great struggle of the modern world because the Ministries of other States are wiser, and because the individual citizens of another country are more generous, than our own?

[Since the address was delivered, four new Universities have been incorporated in England, namely, Liverpool (1903), Leeds (1904), Sheffield (1905), and Bristol (1909), and one new University —the Queen's University of Belfast—has been founded (1908) in Ireland. The number of Universities in the United Kingdom is thus now eighteen. Germany has eleven Technical High Schools, with the power of granting degrees, in addition to the twenty-one older Universities. No useful comparison can be made with the number of Universities in the United States, where there are nearly two hundred institutions called universities, with annual incomes varying from £300,000 down to £1,000.]

If we grant that there was some excuse for the State's neglect so long as the higher teaching dealt only with words, and books alone had to be provided

(for the streets of London and Paris have been used as class-rooms at a pinch), it must not be forgotten that during the last hundred years not only has knowledge been enormously increased, but things have replaced words, and fully equipped laboratories must take the place of books and class-rooms if University training worthy of the name is to be provided. There is much more difference in size and kind between an old and a new University than there is between the old caravel and a modern battleship, and the endowments must follow suit.

What are the facts relating to private endowment in this country? In spite of the munificence displayed by a small number of individuals in some localities, the truth must be spoken. In depending in our country upon this form of endowment, we are trusting to a broken reed. If we take the twelve English University Colleges, the forerunners of Universities unless we are to perish from lack of knowledge, we find that private effort during sixty years has found less than £4,000,000; that is, £2,000,000 for buildings, and £40,000 a year income. This gives us an average of £166,000 for buildings, and £3,300 for yearly income.

What is the scale of private effort we have to compete with in regard to the American Universities?

In the United States, during the last few years, Universities and colleges have received more than

£40,000,000 from this source alone; private effort supplied nearly £7,000,000 in the years 1898-1900.

[The gifts and bequests to education in the United States reach a total of about £5,000,000 annually; and during the forty years from 1873 to 1913 amounted to nearly £100,000,000.]

Next consider the amount of State aid to Universities afforded in Germany. The buildings of the new University of Strassburg have already cost nearly a million; that is, about as much as has yet been found by private effort for buildings in Manchester, Liverpool, Birmingham, Bristol, Newcastle, and Sheffield. The Government annual endowment of the same German University is more than £49,000.

This is what private endowment does for us in England, against State endowment in Germany.

But the State does really concede the principle; its present contribution to our Universities and colleges amounts to £155,600 a year. No capital sum, however, is taken for buildings. The State endowment of the University of Berlin in 1891-2 amounted to £168,777.

[In Germany, State subsidies provide the main part of the incomes of the twenty-one Universities. The annual expenditure for the Universities from State funds amounts in round numbers to £1,800,000. In 1913 the expenditure of the Univer-

sity of Berlin was £242,000; and of this amount £200,000, or about 83 per cent., was derived from State funds.]

When, then, we consider the large endowments of University education both in the United States and Germany, it is obvious that State aid only can make any valid competition possible with either.

[Our State grants to University education in the ten years from 1903 to 1913 are shown in the subjoined table. It will be noticed that the grant to Universities and Colleges in Great Britain is now about £200,000 greater than it was when Sir Norman Lockyer appealed for increased endowment. When the first additional grant of £75,000 a year was made, Mr. Balfour, then the Prime Minister, stated that it was given as the result of Sir Norman Lockyer's appeal (see *Nature*, June 21, 1904, p. 271).

	Universities and Colleges of Great Britain	Imperial College of Science and Technology, London.	Universities and Colleges in Ireland (Net Grant).	TOTAL.
	£	£	£	£
1903-1904	97,000	23,042	4,800	124,842
1904-1905	128,000	21,554	4,800	154,354
1905-1906	174,000	22,723	5,050	201,773
1906-1907	176,000	23,750	4,861	204,611
1907-1908	176,000	23,737	4,700	204,437
1908-1909	196,000	20,000	4,700	220,700
1909-1910	191,000	20,000	32,850	243,850
1910-1911	191,000	20,000	168,000	379,000
1911-1912	276,500	20,000	186,256	482,756
1912-1913	287,000	20,000	130,000	437,000

About 15 per cent. of the income of State-aided Universities and University Colleges in England is derived from endowments, 16 per cent. from annual grants by Local Authorities, and 35 per cent. from Parliamentary grants. In the case of Welsh colleges, endowments form 7 per cent. of the income, grants by Local Authorities 5 per cent., and Parliamentary grants 54 per cent.

The income from endowments in the case of the Universities and University Colleges receiving Treasury grants is about £95,000 for England and £4,000 for Wales; or, say, £100,000 together. Five Universities in the United States have each a much greater income from private endowment funds alone than the total endowment income of State-aided Universities and University Colleges in Great Britain. They are :—

	£
Harvard University	239,500
Columbia University	199,700
Leland Stanford Junior University ..	177,400
University of Chicago	164,000
Yale University	140,900

Our Treasury grant-in-aid of expenses of Universities and University Colleges in Great Britain is £287,000. The Treasury grants of the United States Government to Universities and Colleges amount to £1,175,000, and the State or City grants for current expenses to £2,940,000, or more than £4,000,000 in all. The contributions of several single States in the United States, from State or City funds, for current expenses of Universities and other institutions of higher education, approach the total amount of the grant made for like purposes in Great Britain, as will be seen in the subjoined table :—

	£
Illinois: University of Illinois	260,000
New York: Cornell University, City College, Normal College	257,000
Wisconsin: University of Wisconsin ..	253,000
Minnesota: University of Minnesota ..	249,000]

The more we study the facts, the more statistics are gone into, the more do we find that we, to a large extent, lack both of the sources of endowment upon one or other, or both, of which other nations depend. We are between two stools, and the prospect is hopeless without some drastic changes. And first among these, if we intend to get out of the present Slough of Despond, must be the giving up of the idea of relying upon private effort.

That we lose most where the State does least is known to Mr. Chamberlain, for in his speech, to which I have referred, on the University of Birmingham, he said: 'As the importance of the aim we are pursuing becomes more and more impressed upon the minds of the people, we may find that we shall be more generously treated by the State.'

Later still, on the occasion of a visit to University College School, Mr. Chamberlain spoke as follows:

'When we are spending, as we are, many millions—I think it is £13,000,000—a year on primary education, it certainly seems as if we might add a little more, even a few tens of thousands, to what we give to University and secondary education.'*

* *Times*, November 6, 1902.

To compete on equal grounds with other nations we must have more Universities. But this is not all—we want a far better endowment of all the existing ones, not forgetting better opportunities for research on the part of both professors and students. Another crying need is that of more professors and better pay. Another is the reduction of fees; they should be reduced to the level existing in those countries which are competing with us—to, say, one-fifth of their present rates, so as to enable more students in the secondary and technical schools to complete their education.

[The seventy-two Universities, colleges, and technical schools in the United States on the accepted list of the Carnegie Foundation for the Advancement of Teaching had, in 1900, 55,800 students. In 1910 they had 88,700—an increase of 62 per cent. In Germany, where the number of Universities has remained stationary, the number of students (exclusive of special students) had grown during the ten years 1900-1910 from about 34,000 to 55,000—an increase of more than 60 per cent. This increase, moreover, is not due to a lowering of standards, but marks an actual increase in the number of regular University students far in excess of the increase due to growing population. There are, in addition, about 16,000 fully qualified day students in the Technical High Schools, or, taking the two together, about 71,000 matriculated students. The total number of full-time day students in all the Universities of the United Kingdom is about 21,000, and of day students in our technical institutions about 2,000.]

Men of science, our leaders of industry, and the chiefs of our political parties all agree that our present want of higher education—in other words, properly equipped Universities—is heavily handicapping us in the present race for commercial supremacy, because it provides a relatively inferior brain-power, which is leading to a relatively reduced national income.

The facts show that in this country we cannot depend upon private effort to put matters right. How about local effort?

Anyone who studies the statistics of modern municipalities will see that it is impossible for them to raise rates for the building and upkeep of Universities. The facts are that our towns are already at the breaking strain. During the last fifty years, in spite of enormous increases in rateable values, the rates have gone up from about 2s. to about 7s. in the pound for real *local* purposes. But no University can be a merely local institution.

How to get more Universities.

What, then, is to be done? Fortunately, we have a precedent admirably in point, the consideration of which may help us to answer this question.

I have pointed out that in old days our Navy was chiefly provided by local and private effort. Fortunately for us those days have passed away; but some twenty years ago, in spite of a large

expenditure, it began to be felt by those who knew, that in consequence of the increase of foreign navies our sea-power was threatened, as now, in consequence of the increase of foreign Universities, our brain-power is threatened.

The nation slowly woke up to find that its enormous commerce was no longer insured at sea, that in relation to foreign navies our own had been suffered to dwindle to such an extent that it was no longer capable of doing the duty which the nation expected of it even in times of peace. At first this revelation was received with a shrug of incredulity, and the peace-at-any-price party denied that anything was needed; but a great teacher arose;* as the facts were inquired into, the suspicion changed into an alarm; men of all parties saw that something must be done. Later the nation was thoroughly aroused, and with an universal agreement the principle was laid down that, cost what it might to enforce our sea-power, our Navy must be made and maintained of a strength greater than those of any two possibly contending Powers. After establishing this principle, the next thing to do was to give effect to it. What did the nation do after full discussion and inquiry? A Bill was brought in in 1888, and a sum of £21,500,000 was voted in order, during the next five years, to inaugurate a large ship-

* Captain Mahan, of the U.S. Navy, whose book, 'On the Influence of Sea-power on History,' has suggested the title of my address.

building programme, so that Britain and Britain's commerce might be guarded on the high seas in any event.

Since then we have spent £120,000,000 on new ships, and this year we spend still more millions on still more new ships. If these prove insufficient to safeguard our sea-power, there is no doubt that the nation will increase them, and I have not heard that anybody has suggested an appeal to private effort.

How, then, do we stand with regard to Universities, recognising them as the chief producers of brain-power and therefore the equivalents of battleships in relation to sea-power? Do their numbers come up to the standard established by the Admiralty principle to which I have referred? Let us attempt to get a rough-and-ready estimate of our educational position by counting Universities as the Admiralty counts battleships. I say rough-and-ready, because we have other helps to greater brain-power to consider besides Universities, as the Admiralty has other ships to consider besides ironclads.

In the first place, let us inquire if they are equal in number to those of any two nations commercially competing with us.

In the United Kingdom we had until quite recently thirteen.* Of these, one is only three years

* These are Oxford, Cambridge, Durham, Victoria, Wales, Birmingham, London, St. Andrews, Glasgow, Aberdeen, Edinburgh, Dublin, and Royal University.

old as a teaching University, and another is still merely an examining board.

In Germany there are twenty-two Universities; in France, under recent legislation, fifteen; in Italy, twenty-one. It is difficult to give the number in the United States, because it is clear, from the tables given in the Report of the Commissioner of Education, that some colleges are more important than some Universities, and both give the degree of Ph.D. But of Universities in title we have 134. Among these, there are forty-six with more than fifty professors and instructors, and thirteen with more than 150. I will take that figure.

Suppose we consider the United States and Germany, our chief commercial competitors, and apply the Admiralty principle. We should require, allowing for population, eight additional Universities at the very lowest estimate.

We see, then, that instead of having Universities equalling in number those of two of our chief competitors together, they are by no means equal to those of either of them singly.

If while we spend so freely to maintain our sea-power our export of manufactured articles is relatively reduced because our competitors beat us in the markets of the world, what is the end of the vista thus opened up to us? A Navy growing stronger every year and requiring larger votes to guard our commerce and communications, and a vanishing

quantity of commerce to guard—a reduced national income to meet an increasing taxation!

The pity is that our Government has considered sea-power alone; that while so completely guarding our commerce it has given no thought to one of the main conditions on which its production and increase depend. A glance could have shown that other countries were building Universities even faster than they were building battleships; were, in fact, considering brain-power first and sea-power afterwards.

Sir John Brunner, in a speech connected with the Liverpool School of Tropical Medicine, stated recently that if we as a nation were now to borrow ten millions of money in order to help science by putting up buildings and endowing professors, we should get the money back in the course of a generation a hundredfold. He added that there was no better investment for a business man than the encouragement of science, and that every penny he possessed had come from the application of science to commerce.

According to Sir Robert Giffen, the United Kingdom as a going concern was in 1901 worth £16,000,000,000.

Were we to put aside £24,000,000 for gradually organising, building, and endowing new Universities, and making the existing ones more efficient, we should still be worth £15,976,000,000—a property well worth defending by all the means, and chief among these brain-power, we can command.

I am told that the sum of £24,000,000 is less than half the amount by which Germany is yearly enriched by having improved upon our chemical industries, owing to our lack of scientific training. Many other industries have been attacked in the same way since; but taking this one instance alone, if we had spent this money fifty years ago, when the Prince Consort first called attention to our backwardness, the nation would now be much richer than it is, and would have much less to fear from competition.

Suppose we were to set about putting our educational house in order, so as to secure a higher quality and greater quantity of brain-power, it would not be the first time in history that this has been done. Both Prussia after Jena and France after Sedan acted on the view :—

'When land is gone and money spent,
Then learning is most excellent.'

After Jena, which left Prussia a 'bleeding and lacerated mass,' the King and his wise counsellors, among them men who had gained knowledge from Kant, determined, as they put it, 'to supply the loss of territory by intellectual effort.'

What did they do? In spite of universal poverty, three Universities, to say nothing of observatories and other institutions, were at once founded, secondary education was developed, and in a few years the mental resources were so well looked after

that Lord Palmerston defined the kingdom in question as ' a country of damned professors.'

After Sedan—a battle, as Moltke told us, ' won by the schoolmaster '—France made even more strenuous efforts. The old University of France, with its ' academies ' in various places, was replaced by fifteen independent Universities, in all of which are faculties of letters, sciences, law and medicine.

The development of the University of Paris has been truly marvellous. In 1897-8 there were 12,000 students, and the cost was £200,000 a year.

But even more wonderful than these examples is the ' intellectual effort ' made by Japan, not after a war, but to prepare for one.

The question is, Shall we wait for a disaster and then imitate Prussia and France; or shall we follow Japan and thoroughly prepare by ' intellectual effort' for the industrial struggle which lies before us?

Such an effort seems to me to be the first thing any national or imperial scientific organisation should endeavour to bring about.

Research.

When dealing with our Universities I referred to the importance of research, as it is now generally acknowledged to be the most powerful engine of education that we possess. But education, after all, is but a means to the end, which, from the national point of view, is the application of old and the production of new knowledge.

Its national importance apart from education is now so generally recognised that in all civilised nations except our own means for research are being daily more amply provided for all students after they have passed through their University career; and, more than this, for all who can increase the country's renown or prosperity by the making of new knowledge, upon which not only commercial progress, but all intellectual advance must depend.

I am so anxious that my statement of our pressing, and indeed imperative, needs in this direction should not be considered as resting upon the possibly interested opinion of a student of science merely that I must trouble you with still more quotations.

Listen to Mr. Balfour :—

'I do not believe that any man who looks round the equipment of our Universities or medical schools or other places of education can honestly say in his heart that we have done enough to equip research with all the costly armoury which research must have in these modern days. We, the richest country in the world, lag behind Germany, France, Switzerland, and Italy. Is it not disgraceful? Are we too poor or are we too stupid?' *

It is imagined by many who have given no thought to the matter that research should be closely allied with some application of science being utilised at the time. Nothing could be further from

* *Nature*, May 30, 1901.

the truth; nothing could be more unwise than such a limitation.

Surely all the laws of Nature will be ultimately of service, and therefore there is much more future help to be got from a study of the unknown and the unused than we can hope to obtain by continuing the study of that which is pretty well known and utilised already. It was a King of France, Louis XIV, who first commended the study of the *même inutile*. The history of modern science shows us more and more as the years roll on the necessity and advantage of such studies, and therefore the importance of properly endowing them; for the production of new knowledge is a costly and unremunerative pursuit.

Years ago we had Faraday apparently wasting his energies and time in playing with needles; electricity now fills the world. To-day men of science in all lands are studying the emanations of radium; no research could be more abstract; but who knows what advance in human thought may follow or what gigantic world-transforming superstructure may eventually be raised on the minute foundation they are laying?

If we so organise our teaching forces that we can use them at all stages, from the gutter to the University, to sift out for us potential Faradays—to utilise the mental products which otherwise would be wasted—it is only by enabling such men to con-

tinue their learning after their teaching is over that we shall be able to secure the greatest advantage which any educational system can afford.

It is now more than thirty years ago that my attention was specially drawn to this question of the endowment of research—first, by conversations with M. Dumas, the permanent secretary of the Academy of Sciences, who honoured me by his friendship; and, secondly, by my association with Sir Benjamin Brodie and Dr. Appleton in their endeavours to call attention to the matter in this country. At that time a general scheme of endowment suggested by Dumas was being carried out by Duruy. This took the form of the 'Ecole spéciale des Hautes Etudes'; it was what our fellowship system was meant to be—an endowment of research of post-graduate students in each seat of learning. The French effort did not begin then.

I may here tell, as it was told me by Dumas, the story of Léon Foucault, whose many discoveries shed a glory on France and revived French industry in many directions.* In 1851, when Prince Napoleon was President of the Republic, he sent for Dumas and some of his colleagues, and told them that during his stay in England, and afterwards in his study of the Great Exhibition of that year, he had found there a greater industrial development

* See *Proc. R. S.* vol. xvii. p. lxxxiii.

than in France, and more applications of science, adding that he wished to know how such a state of things could be at once remedied. The answer was that new applications depended upon new knowledge, and that therefore the most direct and immediate way was to find and encourage men who were likely by research in pure science to produce this new knowledge. The Prince-President at once asked for names; that of Léon Foucault was the only one mentioned during the first interview.

Some time afterwards—to be exact, at about eleven in the morning of December 2—Dumas's servant informed him that there was a gentleman in the hall named Foucault, who wished to see him, and he added that he appeared to be very ill. When shown into the study, Foucault was too agitated to speak, and was blind with tears. His reply to Dumas's soothing questions was to take from his pockets two rolls of banknotes, amounting to 200,000 francs, and place them on the table. Finally, he was able to say that he had been with the Prince-President since eight o'clock that morning, discussing the possible improvement of French science and industry; and that Napoleon had finally given him the money, requesting him to do all in his power to aid the State. Foucault ended by saying that, on realising the greatness of the task thus imposed upon him, his fears and feelings had got the better of him,

for the responsibility seemed more than he could bear.*

The movement in England to which I have referred began in 1872, when a society for the organisation of academical study was formed in connection with the inquiry into the revenues of Oxford and Cambridge, and there was a famous meeting at the Freemasons' Tavern, Mark Pattison being in the chair. Brodie, Rolleston, Carpenter, Burdon-Sanderson, were among the speakers, and the first resolution carried was, 'That to have a class of men whose lives are devoted to research is a national object.' The movement died in consequence of the want of sympathy of the University authorities.†

In the year 1874 the subject was inquired into by the late Duke of Devonshire's Commission; and after taking much remarkable evidence, including that of Lord Salisbury, the Commission recommended to the Government that the then grant of £1,000, which was expended, by a committee appointed by the Royal Society, on instruments needed in researches carried on by private individuals, should be in-

* In order to show how history is written, what actually happened on a fateful morning may be compared with the account given by Kinglake: 'Prince Louis rode home and went in out of sight. Then for the most part he remained close shut up in the Elysée. There, in an inner room, still decked in red trousers, but with his back to the daylight, they say he sat bent over a fireplace for hours and hours together, resting his elbows on his knees, and burying his face in his hands.'—*Crimean War*, vol. i. p. 245.

† See *Nature*, November and December, 1872.

creased, so that personal grants should be made. This recommendation was accepted and acted on; the grant was increased to £4,000, and finally other societies were associated with the Royal Society in its administration. The committee, however, was timorous, possibly owing to the apathy of the Universities and the general carelessness on such matters, and only one personal grant was made; the whole conception fell through.

Meantime, however, opinion has become more educated and alive to the extreme importance of research to the nation, and in 1891 a suggestion was made to the Royal Commission which administers the proceeds of the 1851 Exhibition that a sum of about £6,000 a year available for scholarships should be employed in encouraging post-graduate research throughout the whole Empire. As what happened is told in the Memoirs of Lord Playfair, it is not indiscreet in me to state that when I proposed this new form of the endowment of research it would not have surprised me if the suggestion had been declined. It was carried through by Lord Playfair's enthusiastic support. This system has been at work ever since, and the good that has been done by it is now generally conceded.

It is a supreme satisfaction to me to know that in this present year of grace the national importance of the study of the *même inutile* is more generally recognised than it was during the times to which I

have referred in my brief survey; and, indeed, we students are fortunate in having on our side in this matter two members of His Majesty's Government, who two years ago spoke with no uncertain sound upon this matter :—

'Do we lack the imagination required to show what these apparently remote and abstract studies do for the happiness of mankind? We can appreciate that which obviously and directly ministers to human advancement and felicity, but seem, somehow or another, to be deficient in that higher form of imagination, in that longer sight, which sees in studies which have no obvious, necessary, or immediate result the foundation of the knowledge which shall give far greater happiness to mankind than any immediate, material, industrial advancement can possibly do; and I fear, and greatly fear, that, lacking that imagination, we have allowed ourselves to lag in the glorious race run now by civilised countries in pursuit of knowledge, and we have permitted ourselves so far to too large an extent to depend upon others for those additions to our knowledge which surely we might have made for ourselves.'*

'I would remind you that all history shows that progress—national progress of every kind—depends upon certain individuals rather than upon the mass. Whether you take religion, or literature, or political

* Mr. Balfour, *Nature*, May 30, 1901.

government, or art, or commerce, the new ideas, the great steps, have been made by individuals of superior quality and genius, who have, as it were, dragged the mass of the nation up one step to a higher level. So it must be in regard to material progress. The position of the nation to-day is due to the efforts of men like Watt and Arkwright, or, in our own time, to the Armstrongs, the Whitworths, the Kelvins, and the Siemenses. These are the men who, by their discoveries, by their remarkable genius, have produced the ideas upon which others have acted and which have permeated the whole mass of the nation and affected the whole of its proceedings. Therefore what we have to do, and this is our special task and object, is to produce more of these great men.' *

I finally come to the political importance of research. A country's research is as important in the long run as its battleships. The most eloquent teaching as to its national value we owe to Mr. Carnegie, for he has given the sum of £2,000,000 to found a system of endowments, his chief purpose being, in his own words, ' to secure if possible for the United States of America leadership in the domain of discovery and the utilisation of new forces for the benefit of man.'

[The Carnegie Institution of Washington was founded by Mr. Andrew Carnegie on January 28,

* Mr. Chamberlain, *Times*, January 18, 1901.

1902, when he gave to a board of trustees an endowment of registered bonds of the par value of £2,000,000. To this fund an addition of £400,000 was made by Mr. Carnegie on December 10, 1907, and a further addition of £2,000,000 was made by him January 19, 1911; so that the present endowment of the institution has a par value of £4,400,000, yielding an annual interest of 5 per cent. on this amount.

The most recent issue of the Year Book of the institution provides instructive details as to expenditure of the funds available.

The following list shows the amounts of the grants made by the trustees of the institution for the year 1914, and the purposes to which they are being devoted :—

	£
Administration	10,000
Publication	12,000
Division of Publications	2,000
Departments of Research	137,929
Anthropology	4,000
Embryology	5,380
Minor Grants	18,980
Index Medicus	2,500
Insurance Fund	5,000
Reserve Fund	50,000
Exhibit at Panama-Pacific International Exposition	2,000
	£249,789

The next table shows the departments of scientific investigation to which the more important grants were made by the trustees for the financial year 1912-13, and the amounts allotted from these grants by the executive committee during the year :—

	£
Department of Botanical Research ..	7,601
Department of Experimental Evolution	19,028
Geophysical Laboratory	15,600
Department of Historical Research ..	5,920
Department of Marine Biology ..	6,378
Department of Meridian Astronomy ..	5,036
Nutrition Laboratory	9,310
Division of Publications (office expenses)	1,800
Solar Observatory	33,126
Department of Terrestrial Magnetism	42,053
Researches in Anthropology	1,400
Researches in Embryology	3,000
	£150,252

The Parliamentary grant-in-aid of scientific investigation amounts to about £100,000 annually, or £50,000 less than that made to the various departments of the Carnegie Institution for purely scientific purposes. Nearly half the amount of our annual grant is for the National Physical Laboratory and the Meteorological Office, which may be considered as public services. Even if we include the grant of £33,000 from the Development Fund for agricultural research, and the £57,000 available for research under the Insurance Act, we have the fact that a private benefactor has made more provision for scientific investigation than is afforded by the richest country in the world.]

Here is a distinct challenge to Britain. Judging by experience in this country, in spite of the magnificent endowment of research by Mond and Lord Iveagh, the only source of possible competition in the British interest is the State, which certainly could not put the 1/8,000th part of the accumulated wealth

of the country to better use; for without such help both our Universities and our battleships will become of rapidly dwindling importance.

It is on this ground that I have included the importance of endowing research among the chief points to which I have been anxious to draw your attention.

The Need of a Scientific National Council.

In referring to the new struggle for existence among civilised communities I pointed out that the solution of a large number of scientific problems is now daily required for the State service, and that in this and other ways the source and standard of national efficiency have been greatly changed.

Much evidence bearing upon the amount of scientific knowledge required for the proper administration of the public departments, and the amount of scientific work done by and for the nation, was brought before the Royal Commission on Science presided over by the late Duke of Devonshire now more than a quarter of a century ago.

The Commission unanimously recommended that the State should be aided by a scientific council in facing the new problems constantly arising.

But while the Home Government has apparently made up its mind to neglect the advice so seriously given, it should be a source of gratification to us all to know that the application of the resources of

modern science to the economic, industrial, and agricultural development of India has for many years engaged the earnest attention of the Government of that country. The Famine Commissioners of 1878 laid much stress on the institution of scientific inquiry and experiment designed to lead to the gradual increase of the food supply and to the greater stability of agricultural outturn, while the experience of recent years has indicated the increasing importance of the study of the economic products and mineral-bearing tracts.

Lord Curzon has recently ordered the heads of the various scientific departments to form a board, which shall meet twice annually, to begin with, to formulate a programme and to review past work. The board is also to act as an advisory committee to the Government,* providing among other matters for the proper co-ordination of all matters of scientific inquiry affecting India's welfare.

The importance of such a board is many times greater at home, with so many external as well as internal interests to look after—problems common to peace and war, problems requiring the help of the economic as well as of the physical sciences.

Without such a machinery as this, how can our Ministers and our rulers be kept completely informed on a thousand things of vital importance? Why should our position and requirements as an

* *Nature*, September 4, 1902.

industrial and thinking nation receive less attention from the authorities than the head-dress of the Guards? How, in the words of Lord Curzon,* can 'the life and vigour of a nation be summed up before the world in the person of its sovereign' if the national organisation is so defective that it has no means of keeping the head of the State informed on things touching the most vital and lasting interests of the country? We seem to be still in the Palæolithic Age in such matters, the chief difference being that the sword has replaced the flint implement.

Some may say that it is contrary to our habit to expect the Government to interest itself too much or to spend money on matters relating to peace; that war dangers are the only ones to be met or to be studied.

But this view leaves science and the progress of science out of the question. Every scientific advance is now, and will in the future be more and more, applied to war. It is no longer a question of an armed force with scientific corps; it is a question of an armed force scientific from top to bottom. Thank God the Navy has already found this out. Science will ultimately rule all the operations both of peace and war, and therefore the industrial and the fighting population must both have a large common

* *Times*, September 30, 1902.

ground of education. Already it is not looking too far ahead to see that in a perfect State there will be a double use of each citizen—a peace use and a war use; and the more science advances, the more the old difference between the peaceful citizen and the man at arms will disappear. The barrack, if it still exists, and the workshop will be assimilated; the land unit, like the battleship, will become a school of applied science, self-contained, in which the officers will be the efficient teachers.

I do not think it is yet recognised how much the problem of national defence has thus become associated with that with which we are now chiefly concerned.

These, then, are some of the reasons which compel me to point out that a scientific council, which might be a scientific committee of the Privy Council, in dealing primarily with the national needs in times of peace, would be a source of strength to the nation.

To sum up, then. My earnest appeal to you is to gird up your loins and see to it that the science of the British Empire shall no longer remain unorganised. I have endeavoured to point out to you how the nation at present suffers from the absence of a powerful, continuous, reasoned expression of scientific opinion, urging in season and out of season that we shall be armed as other nations are, with

efficient Universities and facilities for research to uphold the flag of Britain in the domain of learning and discovery, and what they alone can bring.

I have also endeavoured to show how, when this is done, the nation will still be less strong than it need be if there be not added to our many existing councils another, to secure that even during peace the benefits which a proper co-ordination of scientific effort in the nation's interest can bring shall not be neglected as they are at present.

I have done what I feel to be my duty in bringing the present condition of things before you. It is now your duty, if you agree with me, to see that it be put right. You can if you will.

BRITISH IMPERIALISM.

GERMAN KULTUR DEFINED.

In any consideration which is given to the working conditions which govern our national welfare, we must not lose sight of the fact that, as the leader of the greatest Empire the world has known, we have to assume great responsibilities to the constituent parts of the Empire, and to the world at large. Whether we do so adequately is another matter, but the fact remains that men, after their primary wants are satisfied, seek for higher culture. It is this aspect of human activity which keeps the world moving and is the embodiment of the Christian doctrine. Certain it is that without the will to live for a definite objective life would cease to have any attraction for individuals. Goethe admirably expresses it in the following lines :—

> ' He only gains his freedom and existence
> Who daily conquers them anew.'

Leaders of German thought have long since recognised this aspect of human existence, and have

developed ideals now known to us as 'German Kultur.' These ideals are roughly as follows :—

(1) The equalisation of all opportunities for the individuals in the State.

(2) The preparation and development of individuals, through Education and Science, for the duties which lie before them as citizens of the State.

(3) That the duties which such individuals shall render to the State shall be more efficiently performed than the duties which the citizens of other nations may render to their respective States.

(4) That the various forces which constitute the life of the State, such as Politics, the Army, Navy, Industry, Science and Education shall be organised in their respective spheres of activity, and work cohesively for the national purpose.

The question we have to solve is whether these German ideals have been established upon principles which in all of their essentials are sound from the Democratic and Christian point of view : we think they have. But the rocks upon which these ideals have been broken, for the present, are Feudalism, absolute Monarchism, and Militarism. The absolute Monarch, *i.e.*, the Kaiser, has made the ideals subservient to his own purpose, and taken as a whole,

from the Kaiser's standpoint, we find a revival of an old economic principle.

If we examine our history* we will find that no large or varied economic activity has been possible under the ascendancy of Feudalism or absolute Monarchism. Whilst Feudalism and absolute Monarchism may have been indispensable, in the days when men were not as intelligent or educated as they are to-day, for the preservation of order and public defence, it is certainly out of place in this age of Democracy. In the days of Plato we find that the governing factor in the life of the State was then, in an extreme form, the subordination of the individual to the will of the State. Among the ruling classes there was a contempt for those citizens who were engaged in Industrial occupations; every form of production, with a partial exception in favour of agriculture, was branded as unworthy of a free man; the only noble forms of activity were considered to be those directly connected with public life, whether military or administrative, and even Plato was impressed with the advantage of specialisation and organisation in the life of the State. He explains clearly how the different wants and capacities of individuals demand and give rise to mutual services, and how, by the restriction of each to the sort of occupation to which, by his position, abilities and training, he is best adapted, everything needful for

* *Encyclopaedia Britannica*, vol. XIX, pp. 349–50.

the whole is more easily and better produced or effected.

These views held sway until we reach Aristotle, and we find this great thinker modifying the views held by Plato. Aristotle traced the origin of society, not to economic necessities, but to the natural social impulses in the human constitution; the nature of the social union, when thus established, being determined by the partly spontaneous, partly systematic combination of diverse activities; and he respects the independence of the latter whilst seeking to effect their convergence. On these grounds he opposes himself to the suppression of personal freedom and initiative, and the excessive subordination of the individual by the State. Aristotle summarily rejects many of the other theories held by Plato, but the point we desire to emphasise is this, that German Kultur, in principle, was advocated by Plato for precisely the same purpose as the Kaiser, and other rulers of Germany, had in view prior to the declaration of war. Aristotle seems to have been more democratic in his sympathies, except in so far that he advocated the exclusion, from any share in the government of the State, of the immediate cultivators of the soil, the artificers, and mechanics, as he held the view that they were apt to be debased by the nature of their occupations. These views no doubt conform to those held by the advocates of German Militarism.

We have now shown that ' German Kultur ' as exemplified in the Kaiser and his military school, is nothing new, but is a glorified expression of the views held by the ancients. The subtle feature of the new Kultur, however, is in the higher intellectual development of the citizens of the German State through Education and Science in order that they shall—

(*a*) the more efficiently sustain the Army and Navy out of the profits of Industry;

(*b*) as members of the Army and Navy provide more efficient cannon fodder, and be able to conduct the Great War on scientific principles.

Whilst, therefore, we may condemn ' German Kultur ' as exemplified by the military school in Germany, let us examine the reason of the successful accomplishment of the objective the Kaiser and his military school have had in view. We do not have to go far for the solution, and it is this :—If we exclude Militarism, and all it stands for, from what is known as ' German Kultur,' we have a set of ideals remaining which have a vital, sustaining, and elevating influence. In the words of Professor Cramb, ' Germany may or may not attain the world Empire of which she dreams; but in the race for spirits dominion, the mightier Empire of human thought, who is her rival? Where even is her competitor? Not England assuredly : for in that region England in the twentieth century has a place

retrograde almost as Austria or Spain.' We are not inclined to be as pessimistic as to the future as Professor Cramb, for we have the capacity to equal the German standard if we will but organise. The want of result is simply due to want of organisation. Our leading men of science, education, and industry are as great as those of Germany, but we have, as a nation, not been educated to appreciate the significance of the words co-ordination, cohesion and organisation.

Whilst we may destroy Germany as a military Power, yet we can never destroy her power as an intellectual nation, for her methods of organisation ensure continuity of policy and quality. And this brings us to the point where we must ask ourselves, What have we to offer in this sphere of activity, as the leaders in the greatest Empire of the world?

Professor Cramb defines the aim of British Imperialism as follows :—' To give all men within its bounds an English mind; to give all who come within its sway the power to look at the things of man's life, at the past, at the future, from the standpoint of an Englishman; to diffuse within its bounds that high tolerance in Religion which has marked this Empire from its foundation; that reverence yet boldness before the mysteriousness of life and death characteristic of our great poets and our great thinkers; that higher justice and a larger freedom which, rightly or wrongly, we associate with the

temper and character of our race whenever it is dominant and secure.'

But are these political ideals enough? As a counterpart to the German system of Militarism and morals, and as the basis of a system of intellectual culture they are excellent, but, by themselves, are they sufficient to satisfy the aspirations of men who seek for higher culture? And who can deny that men, no matter in what station of life they may be placed, have got innermost thoughts of that kind?

To hold the view that the sole purpose of our Empire in the past has been to give all men within its bounds an English mind, is undoubtedly a correct interpretation of our policy of granting that larger freedom which we associate with our race, but what of the future? What have we to offer as a substitute for the ideals of Germany in the intellectual dominion or for the advancement of human welfare? The answer is, of course, nothing.

The shock of the Great War must assuredly have awakened us to the responsibility which we, as the rulers of a great Empire, have assumed, and to the realisation of the fact that our shortcomings in the intellectual sphere of activity are many. And to what is it due? To the party system of government; to the belief that all wisdom was centred in the framers of political constitutions, and in allowing the initiative in all matters pertaining to the development of science, education, and industry to remain

with them. Our time has been wasted in waiting for the settlement of political quarrels; have we learnt our lesson? Will the leaders of British industry and science come together and work for the good of the nation and Empire? Will they open up a new outlook and set of ideals of British origin for the Empire, so that all who may come within its sway may look at the things of life from the standpoint of a Briton? It cannot be said that attempts have not been made. Take that remarkable address of Sir Norman Lockyer's to the British Association at Stockport in 1903 on the 'Influence of Brain Power in History.' It is almost prophetic in detail, but yet how many people are there who have absorbed its significance? Very few indeed. Very many have realised its importance, but have been content to leave its development to the party system of government. To leave the initiative with the Government in these matters is, we believe, wrong in principle, for the officials cannot be expected by the nature of the work which they follow to have the requisite experience and knowledge to enable them to follow the development of the problems at issue to their logical conclusion. The officials must first of all give consideration to the political views of those who control the Government, and whenever such considerations intervene in questions relating to the development of industry and of science impartial judgment cannot be exercised.

But apart from this it cannot be expected that the members of a Government or their officials can be the best judges of the working conditions which are best suited for the progress of national welfare in industry and science. These questions are not political in character—they are essentially practical; hence they require the practical and scientific mind to evolve them. This brings us to the conclusion, therefore, that the leaders of industry and science must establish their own organisation so as to retain the initiative in their own hands, and to shape out the working conditions essential for the nation's progress and welfare, and incidentally for the progress and welfare of the Empire, in co-operation with the Government of the day, or without. In this age the greatness of a nation is determined by its intellectual efficiency and by the guidance which it can give to the inhabitants of the weaker States in the progress of human welfare. Shall we again resume that task in this sphere of activity?

> 'Dream ye of peaceful sway?
> Dream on, who dream it may.
> War still is empire's word!
> Peace? by the Victor's sword!'

* * * * * *

Conclusion.

As we have already indicated, the working conditions in which we lived prior to the declaration of

war have undergone considerable modification, and we hope will never return.

We have had a few prophets amongst us who have foreseen the present crisis, and had we followed their advice the present war would not have been possible. In the military sphere of activity we have had Lord Roberts; in the intellectual we have had Sir Norman Lockyer and Professor Cramb; and we have also had the crusade by the Tariff Reformers. The failure of the campaign initiated by the latter group is due entirely to their want of appreciation of the intellectual factors. Several well-known Tariff Reform writers and politicians consider, for instance, that the great progress made by Germany is entirely due to her fiscal system, and they draw the same analogy with regard to the United States. We have had Tariff Reform excursions to Germany in order to show our workmen the excellent conditions in which German workmen lived, and how prosperous they had become under the system of protection. To attribute the great prosperity of German and American industry primarily to protection is wrong—it is primarily due to the high standard of their intellectual qualities. One is, however, a reflex of the other, and neither can succeed alone. When the war is finished we shall have to consolidate our position, and how is it to be done? There has never been a period in our history, like the present, when it was more essential to have a

clear conception of what Empire means. The permanence and prosperity of the Empire can only be made secure by strengthening its basis with brains, science, education, and the organisation of its industrial and national resources. Fiscal measures are secondary considerations, which can be employed as occasion serves to strengthen the props upon which the Empire should in reality be based.

J. T. P.

1*st March*, 1915.

STEEL INDUSTRY.

OPPORTUNITIES FOR BRITAIN.

By WILLIAM LORIMER, *LL.D., Chairman of the Steel Company of Scotland, Ltd., Chairman North British Locomotive Co., Ltd.*

[This very interesting article by Dr. Lorimer has been added for general information; it fully confirms the views already expressed herein and should receive the consideration of all who are concerned in the welfare of British industry.—J. T. P.]

THE war is affecting practically every industry in the country. In some cases its influence may be temporary, while in others it may be permanent. The purpose of this article is to inquire what is likely to be its effect—favourable or the reverse—on the steel trade of Great Britain, and whether it will provide an opportunity for regaining some of the markets which have been lost in recent years.

The output of the principal steelmaking countries of the world in 1913 was as follows, stated in millions of tons per annum :—

United States	...	24 million tons.
Germany ...	...	18 million tons.
United Kingdom	...	7 million tons.
Russia ...	...	4 million tons.
Austria-Hungary	...	3½ million tons.
Belgium ...	...	2½ million tons.

Canada also is becoming a steel-producing country, and though its output is small in comparison with the above figures, it is increasing and will become important. A beginning has also been made with the production of steel in India and Australia, while one of the largest and most valuable deposits of iron ore in the world is now being worked in Newfoundland.

Continental Production.

The two countries which have increased their production most rapidly during the last five years are Germany and Russia. In both there has been erected recently new plant, which was not working up to its full capacity prior to the war. Germany's chief sources of ore supply are the Minette deposit in Lorraine and Luxemburg, east of the Moselle and north of Metz. This deposit is phosphoric, and consequently the great bulk of the German steel is basic.

In 1870 it was not known that this deposit was to any great extent workable beyond the boundaries of that portion of Lorraine which was annexed by Germany. It is now known that French Lorraine contains a larger quantity of rather better quality than German Lorraine, the approximate figures being :—

French Lorraine ...	3,000 million tons.
German Lorraine...	1,800 million tons.
Luxemburg ...	250 million tons.

The discovery in 1877 of the basic process of steelmaking gave an immense impetus to the development of this deposit, and the output of German Lorraine rose from about one million tons in 1880 to about 30 million tons in 1913. The development of the deposit in French Lorraine has been very rapid recently, and the output in 1913 was about 15 million tons, large quantities of which were exported to Germany and Belgium. Germany also imports about 10 million tons of ore from other sources, chiefly cheap qualities of phosphoric hematite. It will be seen from this that should Germany, as a result of the war, be compelled to surrender Lorraine to France, her sources of ore supply will be seriously affected, and the cost of her purchases will, in all probability, be considerably increased. At present the whole area of the Minette deposit is within the German lines.

Germany has also large reserves of coal, which have been rapidly developed during recent years, and in many cases the steel companies own their own collieries. They have also developed in a marked degree the system of utilising the waste gases from coke ovens and blast furnaces in the process of steel manufacture, and by this means they have reduced the consumption of coal per ton of steel to a minimum.

The United States have enormous supplies of cheap fuel, and also large supplies of fairly high-

grade ores, which, although seldom found in proximity to the steel works, are developed on a very large scale with special arrangements for economical transport, so that as yet comparatively small quantities of ores have been imported. About one-half of the steel produced in the States is acid, and one-half basic.

The increase in the production of steel in the United Kingdom in recent years has been relatively insignificant as compared with the United States or Germany. In steelmaking, as in so many other industries, Great Britain has been a pioneer. We began years before the basic system was invented, and thus have relatively a much larger proportion of our plant devoted to the manufacture of the purer and costlier acid steel than any other country in the world.

Supplies of Ore.

Our output of acid steel has remained practically stationary for the last ten years, being round about four million tons per annum, while our output of basic steel has increased from one million to about three million tons. The primary reason for the absence of growth in the production of acid steel is the difficulty of getting, at a low enough price, increased quantities of the pure ores practically free from phosphorus which are necessary for its manufacture. On the other hand, deposits of phosphoric

ore are found in all parts of the world, and as many of them are of vast extent, they can be worked cheaply, so that basic steel can be produced at a considerably lower cost than acid steel.

In the United Kingdom there are large reserves of low-grade phosphoric ores containing less iron than the Minette deposits of Lorraine, but they are somewhat scattered, and are not always near the coalfields or near existing steel works.

There are also large reserves of coal, but the cost of production of coal, as will be noticed later, has risen very seriously in recent years, and as many of the companies producing steel are comparatively small, and have to buy their pig iron and coal, it has not been possible to utilise waste gas to the same extent as in Germany. Then the wages paid to certain groups of workmen are very high, and no adequate allowance has been made, in fixing wages, for increased facilities for cheapening production. These factors, combined with the National Insurance Act, the Mines Regulation Acts, and similar legislation, have so enhanced the cost of production that foreign competition has become increasingly difficult to meet.

In Russia there are large quantities of both ore and coal, and the principal development has been near the Black Sea. The home market is highly protected, and as yet comparatively small quantities have been available for export.

France, while rich in iron ore, is comparatively poor in reserves of coal. During the past five years there have been considerable developments of iron-ore mines in the West of France, partly controlled by German firms, while quite recently French firms have acquired large interests in the newly discovered coalfield in Kent.

Austria-Hungary is relatively poor in both iron ore and coal reserves; nevertheless a considerable amount of modern steel plant is operated.

Belgium has not much coal and very little ore, but considerable supplies are drawn from Luxemburg, just across the border, and there are extensive modern works near Liége. There are considerable deposits of ore in the Belgian colony in the Congo, but the operation of these will probably belong to the time when we shall have to draw our supplies from the Southern Hemisphere.

Germany Preparing.

At the outbreak of the war the steel trade was nowhere good, but it was better in Germany than in Great Britain. Various causes had been in operation to produce this result. As we know now, long preparation has been made for ' The Day,' and this involved the manufacture of enormous quantities of war material for use by land and sea. Germany's home market is secured to its manufacturers by high protective duties. It is, of course, a truism to say

that a maximum output can be produced at a much cheaper rate per ton than a minimum, and the application of this principle, combined with remunerative prices obtained for work for the home market, has enabled German manufacturers to make a fairly successful effort to capture our export trade and to obtain a footing in our home markets.

This effort has been carefully and systematically organised by a syndicate of manufacturers, who, no doubt, allot the foreign orders to the works best suited to execute them at the lowest cost. This can be done much more easily than would be possible in Great Britain in existing conditions, for an outstanding feature of the German steel industry is that it is controlled by a very few large companies. Incidentally it may be remarked that anti-trust legislation has probably checked to some extent similar methods of combined action in the United States. For some years prior to the war the available plant in that country was not working up to its capacity, and the increase in production has not been relatively as large as that of Germany.

Immediately before the outbreak of the war the steel trade of Great Britain was in a very unsatisfactory condition. At the beginning of 1912 activity in the shipbuilding and other trades had created a good demand for steel in all parts of Europe. Unfortunately for us it happened that coincidently with this occurred the national coal strike, which stopped

production for two months, and had very far-reaching effects. When the coal strike was settled great pressure was put on the steel works for deliveries, and while arrears were being worked off, prices were maintained at a high level. At the same time, however, the pressure for deliveries on German works was never so great, and quite a number of new plants were put to work. The result of these conditions was that large quantities of German material were contracted for by British consumers of steel, and by the middle of 1913 British mills were short of orders, and could only be kept going on a very much reduced output.

British Difficulties.

The increased purchases from Germany at this time were perhaps, in the circumstances, inevitable, but probably few realise how unfavourably our position in international competition has been affected by this strike and by the legislation already referred to. The most serious feature of our present position is the increased cost of production. To take one item only. If we compare the year 1904 with the spring of 1914 it will be found that for the manufacture of one ton of acid steel plates made in Scotland from ores imported from abroad, the cost of the coal used has been increased by no less than 14s. 6d. per ton of plates. This result has been arrived at in spite of improvements in plant reducing the consumption of

coal, and as a matter of fact the small output during the spring of 1914 just about neutralised the effect of the improvements.

Immediately on the declaration of war not only was there an instant cessation of imports of German steel into this country, but German exports to neutral markets were also stopped by the closing of German ports. As our own ports were open and the seas practically clear, it looked as if the world's business in steel might be shared by ourselves and the United States, but it quickly became evident that there was no export business for either country. The magnitude of the struggle and of the interests involved so dislocated international finance that international business was paralysed, and therefore while there was great activity in the production of war material, exports of steel of the ordinary kind were almost entirely suspended. The financial arrangements of the Government have, however, proved very effective, and within the past few weeks there has been a greatly improved demand for steel for export, while the numerous shipbuilding orders recently placed have increased the demand for home consumption.

The Commercial Intelligence Department of the Board of Trade have issued a series of memoranda showing the extent of German trade in neutral markets and the openings they afford for British manufacturers, and it is to be hoped that they will

receive the full and careful study which they deserve. Even in respect of the steel trade alone the details are too numerous to permit of their being embodied in this article, but one or two figures may be given.

The value of iron and steel plates and sheets exported by Germany in 1912 was £3,523,000, of which over half a million was imported into the United Kingdom, about half as much was sent to India and the Dominions, and the rest to neutral markets. British exports in the year 1913 amounted to £2,813,000.

Germany's exports of rails in 1912 amounted in value to £2,900,600, of which £129,900 represented imports into the United Kingdom, and £205,300 into India and the Dominions. British exports in 1913 amounted to £3,457,800. Of railway wheels and axles complete and tyres and axles loose Germany exported in 1912 £1,377,000, of which the United Kingdom took £40,000, and India and the Dominions £349,000. For the year 1913 British exports amounted to £1,210,000, of which India and the Dominions took £783,000.

British Opportunities.

These are only a few of the figures which might be enumerated, and it is obvious that they indicate a most valuable opportunity for largely increasing our export trade. Some of the countries referred to as neutral markets are no longer neutral, for they

include our Allies—France, Russia, Belgium, and Japan—and they also include such friendly countries as Italy and Roumania, who must resent, and will continue to resent, the economic pressure to which German policy has subjected them.

Such trade as these countries can meanwhile afford must almost of necessity come to us, but we ought to make it our business to retain it in the future. How is this to be done? One thing we ought emphatically not to depend on is sentiment. No doubt it will help us for a time, but it would be weakness and folly to trust to it permanently.

The Government of the Commonwealth has forbidden Government purchases from Germany in the future, and that is probably indicative of the feeling that will prevail among our Dominions and Dependencies. But we have to think of the ordinary consumer, who is an important factor in the maintenance of this industry. At present he is a sincere and full-hearted patriot, but ' when the hurly-burly's done, when the battle's lost and won,' and he settles down to the old conditions of peaceful trading, it will be in no way surprising if his love for the cheapest market so revives that if patriotic sentiment were put in one scale and half a crown a ton in the other, the former would kick the beam.

In considering, then, what is to be done, let it be clearly understood that nothing is imported into this country which cannot be equally well made here,

and that every neutral market in the world is open to us at a price. The one essential factor in the extension and retention of our trade is a reduction of costs, both in production and in distribution. With respect to the latter, the German system is one of combination as against our system of individualism, and it has certainly produced striking results. It will be well worth while for our home manufacturers to consider the feasibility of a closer alliance of the present producing companies, so that orders for all classes of steel may be executed at the mills best suited for the various products. Such an alliance would facilitate the creation of a better selling organisation, and it should keep its members in close touch with the official British Trade Commissioners settled in all parts of the world, who are eager to help British manufacturers, and who are constantly rendering valuable assistance to all who apply for it.

With respect to reduced cost of production, while, as already indicated, the conditions at home are not so favourable as in Germany for the utilisation of waste gas, still, wherever this and the utilisation of exhaust steam are possible, the subject should have the most careful consideration.

Attitude of Trade Unions.

With regard to wages, manufacturers have not been quite fairly treated by the trade unions. When

the making of open-hearth steel began, a 25-ton furnace was a large one, and the wage rate per ton was fixed on this basis. Now furnaces of 60 tons capacity are quite common, but the rate per ton remains the same. But wages are either high or low only relatively to production. American wages are the highest in the world, but they are really lower than ours in relation to the output of the mills and furnaces. A sustained maximum output will reduce costs, will provide high wages, and will ensure employment; for only through full economic production can demand be regularly maintained. Restriction of output is unsound in principle and mischievous in its effect on employer and workman alike.

There are large markets open to us in Norway, Sweden, the Netherlands, and Switzerland. Hitherto these have been almost monopolised by Germany. In Russia, Italy, Japan, and our own Dominions Germany's predominance is much less marked, but it has nevertheless a very considerable share of the trade which the sympathetic feeling of the allied and friendly countries should make it easy for us to capture, if sufficient energy is displayed and if reasonable prices are quoted. A manufacturer will naturally and properly seek to obtain a reasonable profit on his costs, but these should be costs determined not by the use of obsolete plant, but of an equipment designed and intended to produce the most economical results, so that if present exigencies

give him admission into new markets, he may in the future be able to retain them on his merits.

Defective Business Methods.

During the past two years I have been in many parts of the world, and have heard complaints of our business methods constantly repeated. These may be stated here, though they are not applied exclusively, or even specially, to the steel trade. For instance, Colonial and foreign buyers complain that the British manufacturer will not supply what they want, but what he thinks they should use, because it is what he is in the habit of making. He would do better to act on the principle that it is his business to supply as cheaply as possible what the world's markets require, not something else, and not necessarily something better.

Then, again, if a man wants to buy at a price per kilo. instead of per ton, why put any difficulty in his way? Nothing more is involved than a simple calculation. Or if he wishes to pay in francs, in roubles, or in dollars, why not? It is simply a question of exchange. His catalogues and price-lists ought to be prepared in the language of the country to which they are to be sent, and while currency varies nearly everywhere he should be prepared whenever necessary to express his measurements in metrical dimensions. The point is that we ought to adapt ourselves to the buyer's conditions, and make

it easy and not difficult for him to do business with us.

Preparation should be made not only for an early future, but for a future more remote. As it was in 1870 and afterwards, so is it likely to be again. When the war ends there will be much wastage which will have to be replaced in our Navy and in our mercantile marine, although if the German Fleet is handed over to us as part of our indemnity the expenditure necessary on our Navy will be materially reduced. But all this frightful expenditure by the nations involved, in men and in money—an expenditure which is producing no economic return—will impoverish the world for years. Remunerative expenditure and all expenditure not imperative must be curtailed until the capital destroyed is, at least in part, replaced, and therefore while we may expect a great outburst of trade at the close of the war, it will probably be followed by a period of restricted demand and keen competition. Let this be kept well in view in all preparation for the future.

I am much indebted to my friend and colleague, Mr. Wallace Thorneycroft, for the trouble he has taken in collecting for me the statistical information contained in this article.

THE CHEMICAL INDUSTRIES OF GERMANY.

By PROFESSOR PERCY FRANKLAND, F.R.S.

[This lecture was delivered before the Society of Chemical Industry (Birmingham and Midland Section) in the University of Birmingham, on March 4th, by Professor Percy Frankland, F.R.S., and in view of its great importance it is published herein for general information, and should also be studied by all who are concerned in the welfare of British Industry.—J. T. P.]

THE interest and importance of the subject at the present time are sufficiently obvious. In outlining some of the origins of chemical industry in Germany, the lecturer pointed out how the royal house of Prussia had been frequently associated with chemical enterprise. The Markgrave John was actually surnamed 'the Alchemist,' the Great Elector was a patron of chemistry, and provided a laboratory at Potsdam for the celebrated Kunkel, one of the first to discover phosphorus, who also effected great advances in the manufacture of glass. Frederick the Great established the Royal Berlin porcelain factory, which still occupies some of the original premises.

In the same reign also the chemist Marggraf made those classical investigations on the occurrence of sugar in the vegetable kingdom which later led to the foundation of the beet-sugar industry, which was initially subsidised by Frederick William III, the founder of the University of Berlin, in 1809. (In 1914 the Berlin University had 11,726 students, and received an annual grant from the State of more than £200,000.)

Great industries have developed out of these early steps. From the discovery of phosphorus came the match industry. German annual production of matches is £4,600,000; the British production in 1907 amounted to £775,000, whilst the British consumption in 1910 was estimated at £1,300,000. Again, the porcelain and pottery manufacture had attained great dimensions in Germany, the exports in 1912 amounting to £3,556,000, whilst the glass industry was even on a larger scale, the recent annual exports being more than £7,000,000. Great inconvenience in connection with all scientific work is at present being experienced through the absence of German glass. The important cyanide industry may be said to have taken its origin from the accidental discovery by Diesbach, of Berlin, of Prussian blue in the first decade of the eighteenth century. Germany's annual production of cyanides is now estimated at 10,000 tons (£650,000), or about one-half of the world's production.

The present position of Germany in the sugar industry of the world can be appreciated from the following figures :—

Total Sugar Crop, 1912-13.

	Tons
Cane-sugar	9,211,755
Beet-sugar, European (⅓ German) ..	8,310,000
„ United States	624,064
Total	18,145,819

The United Kingdom annually imports 1,700,000 tons of sugar (£23,000,000).

	Annually produces £	Beet-sugar on Acres
Germany ..	36,000,000 ..	1,300,000
France.. ..	13,000,000 ..	570,000
All Continental countries ..	116,000,000 ..	6,000,000

The beet-sugar industry is of particular interest in connection with the present crisis, because it is an example of an industry which received a most important impetus through the exclusion of British goods (Colonial cane-sugar) from Continental ports during the Napoleonic wars.

This industry again exemplifies how agricultural production can be improved by systematic research such as has been bestowed on it by Germany, thus :

In 1840	100 lb. of beet yielded ..	5.9	lb. sugar
1850	„ „ ..	7.3	„
1870	„ „ ..	8.4	„
1890	„ „ ..	12.5	„
1910	„ „ ..	15.8	„

Again in

1871	mean yield of beet per hectare of land was ..	246	quintals
1910	„ „	300	„

And again in the economy of manufacture

In 1867	coal used on	100 lb.	beet ..	35	lb.
1877	„ „	„	..	24	„
1890	„ „	„	..	10	„
1900	„ „	„	..	7	„

As indicating the great and progressive attention devoted to agriculture, Germany's artificial manure bills for 1888 and 1912 were highly instructive :—

	1888. Tons	1912. Tons
Chile Saltpetre ..	225,000	650,000
Sulphate of ammonia	50,000	500,000
Superphosphate ..	250,000	1,800,000
Basic slag	250,000	2,200,000
Crude potash salts ..	160,000	3,000,000
Lime	—	800,000
Other manures ..	500,000	500,000
Total value ..	£30,000,000	

The following comparison is also of interest :—

Use of Artificial Phosphatic Manures (per annum).

England ..	48 lb.	per 1 acre cultivated
France	105	„ „
Germany ..	105	„ „

The former supremacy of Great Britain in the manufacture of the common chemicals—sulphuric

acid and soda—was referred to, and compared with the production of these materials in 1910.

Production in Tons, 1910.

	Sulphuric Acid	Soda
Germany ..	1,250,000	400,000
England ..	1,000,000	700,000
France	500,000	200,000
United States ..	1,200,000	250,000
World	5,000,000	2,000,000

The substitution of the ammonia-soda for the earlier Le Blanc soda process, and of the contact for the time-honoured leaden chamber process of sulphuric acid manufacture, had no doubt greatly assisted both Germany and America in becoming independent of the British manufacture of these chemicals.

During the past twenty-five years the manufacture of chlorine and caustic soda by the electrolysis of common salt (sodium chloride) has been realised and rapidly extended. This process is carried out on a very large scale in Germany, where extensive use is made of liquefied chlorine. The production of electrolytic chlorine is attended with the simultaneous evolution of large quantities of hydrogen gas, for which uses have been found; thus, for filling the dirigible balloons upon which such hopes of conquest have been based by Germany, whilst in the

oxyhydrogen flame it has been employed for welding, for the cutting even of thick iron structures, and for the manufacture of artificial gems. The artificial production of gems—corundum, ruby, sapphire, &c. —was discovered in France by Michaud, Verneuil, and Paquier, and has been greatly taken up by the Elektrochemische Werke at Bitterfeld, in Germany. More than a ton of these gems, which are identical in chemical composition with the natural gems, are said to be annually produced. Other more important uses for hydrogen have been found for the hardening of fats, and still more recently for the synthetic production of ammonia, to be presently referred to, and which is an industrial achievement of the first magnitude. Cheaper sources of hydrogen than the electrolytic method have been introduced, and notably that depending on the production of water-gas (consisting of equal volumes of hydrogen and carbon monoxide) from steam and coke at a red-heat, the carbon monoxide being subsequently separated from the hydrogen by liquefying it by means of the low-temperature apparatus of Carl von Linde, of Munich.

The discovery of incandescent gas lighting by the Austrian, Count Auer v. Welsbach, and of the metallic filament incandescent electric lamp by the same inventor in 1903, as well as the improvements in the latter effected by Siemens and Halske in 1905 and 1906, have led to the production of these com-

modities on a very large and increasing scale in Germany. Thus :—

	1911	1912
Incandescent gas mantles ..	126,000,000	135,000,000
Metallic filament electric lamps	47,000,000	76,000,000
Carbon filament lamps (production diminishing) ..	25,000,000	21,000,000

The following comparison of the estimated consumption of incandescent gas mantles in different countries for the year 1912 is interesting :—

Germany ..	100,000,000	Belgium ..	3,500,000
America ..	60,000,000	Italy	3,000,000
England ..	38,000,000	Russia ..	1,500,000
France ..	16,000,000		

Ammonia, Nitrates, and Fixation of Free Nitrogen.

During the past century the world's supply of ammonia has been almost exclusively obtained as a by-product in the manufacture of gas, and latterly also from coke-ovens. So backward was Germany in the production of ammonia that as late as 1874 the ammoniacal liquor of their gasworks was allowed to run to waste. All the more remarkable is the state of affairs revealed by the following figures :—

		Tons
In 1890	the world's production of sulphate of ammonia	210,000
1900	„ „ „	500,000
1912	„ „ „	1,330,000
1910	Germany's „ „	300,000
1912	„ „ „	400,000

The principal use of sulphate of ammonia is as a nitrogenous manure, as which it competes with Chile saltpetre (sodium nitrate).

Sulphate of ammonia contains 20.5 per cent. nitrogen
Chile saltpetre (sodium nitrate) 15 „ „

It has already been pointed out that Germany imports 650,000 tons of Chile saltpetre for manure; hence by increasing their output of sulphate of ammonia they have been rendering themselves less dependent on foreign products (nitrate from Chile and sulphate of ammonia from England).

As is well known, one of the most important problems at the present time is to provide the world with nitrate when the deposits in Chile shall have been exhausted. The problem is bound up with the still wider one of the fixation of atmospheric nitrogen. This, again, as is well known, is now accomplished on a large scale by the production of nitric acid from atmospheric nitrogen and oxygen by means of the electric furnace of Birkeland and Eyde, or by the production of calcium cyanamide by passing atmospheric nitrogen over heated calcium carbide. Both these processes involve the use of the electric furnace, in the former for effecting the union of the nitrogen and oxygen, and in the latter for the preliminary production of the calcium carbide. Abundant water-power being necessary for the economic operation of the above processes,

Norway has become their chief centre, whilst Germany has sought other means of nitrogen-fixation which could be carried on within her own territories. The synthesis of ammonia from hydrogen and atmospheric nitrogen under a pressure of 200 atmospheres and at 500° C. in the presence of a catalyst, has been successfully worked out by Haber in conjunction with the Badische Anilin und Sodafabrik, and a plant capable of yielding 130,000 tons of sulphate of ammonia per annum was to have been ready in 1914. The second step in the German programme was to convert the ammonia into nitric acid by burning it in air in the presence of a catalyst. In this way it is hoped to make Germany independent of foreign countries for the nitrate required in the manufacture of explosives. It is asserted that this independence Germany has actually secured at the present moment.

Potash Salts.

The unique deposits of potash salts discovered at Stassfurth in 1857 have been exploited on an increasing scale, and have furnished practically the whole world with potash; the output of crude salts was in

	Tons	£
1881	2,000 ..	
1912	11,000,000 ..	(8,800,000)

In 1911 America alone took potash salts to the value of £3,000,000.

Explosives.

Of the modern high explosives, gun-cotton was discovered by Schoenbein and by Boettger in 1846. The manufacture of nitroglycerine (discovered by Sobrero in Paris in 1847) was first realised by the Swede, Alfred Nobel, in 1862, and it was Nobel who first adopted these powerful explosives for ballistic purposes. Trinitrotoluene, of which so much has been recently heard, was first proposed for filling shells by Haessermann in 1891. It is said to be surpassed, both as regards safety and disruptive effect, by tetranitro-aniline discovered in England by Dr. Fluerschein. The great magnitude of the German explosives industry is seen from the following figures :—

	Tons
Total German production of explosives ..	40,000
or about 1-10th of the estimated world production.	
	£
Germany exported in 1908 to the value of ..	1,000,000
„ „ 1912 „ ..	3,000,000

Artificial Silk.

This remarkable industry, originated by Count Chardonnet in France in 1891, has also been largely developed on German soil. The German production amounts to about 2,000 tons annually (£1,200,000) out of a total world production of about 7,000 tons. French, German, and British patents have largely contributed to the success of this industry.

Industries Dependent on Synthetic Organic Chemistry.

It is in respect of these industries that the world is learning that Germany holds the undisputed supremacy. It is in Germany alone that manufacturers have been found prepared to embark their capital and undertake industrial enterprises of the first magnitude on the advice of the organic chemist. The success which has been achieved by the German manufacturers of artificial dyestuffs, drugs, and perfumes, and the hegemony which they have secured in this branch of industry, has been the frequent subject of warning by professors of chemistry in this country for upwards of a generation. The seriousness of the situation which has arisen through the neglect of those warnings is seen from the following figures :—

	£
Annual value of dyestuffs used in England	2,000,000
„ trade in which these dyes are employed	200,000,000
Workmen dependent on this trade	1,500,000
Total value of dyestuffs imported (1913) ..	1,892,055
„ „ „ from Germany	1,730,821

Thus less than one-tenth of the annual value of the dyestuffs consumed in England is produced in this country. Thus, by controlling the dyestuff industry, Germany indirectly holds in her grip the much larger textile industry.

The manner in which the coal-tar colour industry has extinguished the cultivation of madder, more especially in France, since 1870, and has caused the cultivation of indigo in British India to dwindle almost to nothing since 1897, are now well-known facts in commercial history. They will be fully appreciated by a study of the following figures :—

At the time of the discovery of artificial alizarin (the dyestuff contained in madder) in 1869, the total production of natural alizarin amounted to between 500 and 750 tons (£2,250,000), and in 1870 France had 50,000 acres under madder cultivation.

The production of artificial alizarin was

	Tons
In 1873	100
1877	750
1884	1,350
1900	2,000

(4-5ths of this produced in Germany.)

Again, with regard to indigo, in 1896 the world's production of plantation indigo was valued at about £4,000,000, of which four-fifths was obtained from British India.

Export of Indigo from British East Indies.

	£
1896	3,569,670
1899	1,980,319
1902	1,234,837
1905	553,405
1908	424,849
1911	225,000
1913–14	60,000–70,000

Since the introduction of artificial indigo the price of indigo has been reduced by more than one-half, but since the outbreak of the war the price of indigo has advanced by 350 per cent.

Much inconvenience has been experienced also in the shortage of artificial drugs and consequent high prices, more especially at the beginning of the war, as even the simplest of these products were almost exclusively made in Germany. The manufacture of some of these is, however, now being successfully carried on in England.

Again, the shortage of organic chemicals required for research purposes, which practically all come from Germany, is occasioning most serious difficulties in our university laboratories.

For the manufacture of dyestuffs and similar synthetic products Germany was formerly largely dependent on England for the raw material—coal tar. But in this case, again, the ambition of Germany to become in all respects independent and self-contained has led her in recent years to make the most strenuous efforts to recover the maximum amount of coal tar both from the manufacture of gas and from coke ovens, which endeavour has been promoted by the enormous growth in her iron and steel industries. Thus in 1897 Germany obtained only 52,000 tons of coal tar from coke ovens, whilst in 1908 she obtained no fewer than 632,400 tons from that source, besides 300,000 tons from the